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SPECIFICATIONS

FOR

STREET ROADWAY PAVEMENTS

BY

S. WHINERY

M. Am. Soc. C. E.



NEW YORK

THE ENGINEERING NEWS PUBLISHING COMPANY

1907

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INTRODUCTORY.

In addition to their value as memoranda and aids in preparing specifications for a particular project, carefully prepared general specifications, embodying the latest approved practice, sometimes supply the most useful and acceptable brief treatises upon any particular branch of engineering work. It has been partly with this thought in mind that the following set of specifications for standard street pavements, has been prepared and is now offered to city engineers and municipal authorities.

To widen their range and increase their usefulness, copious foot notes have been added, referring to alternative requirements and methods of construction, and giving some of the reasons for the preference or adoption of the construction called for in the specifications. It is recognized that in a good many matters of detail embraced in these specifications there is difference of opinion among able engineers, many of whom are at least as competent as the writer to determine what is best. They are not offered in a dogmatic spirit, or with the hope that all the provisions found therein will be accepted. If they shall be of some assistance in bringing about correct standards for such specifications, their preparation will have been justified.

Theoretically, three general classes of engineering specifications may be noted. In the first the aim of the engineer is to specify the end or result that it is desired to secure, leaving the contractor free to originate and follow the methods by which these results are to be attained. In the second the engineer aims to secure the desired end, by specifying in detail the materials and the methods which in his opinion will accomplish the purpose, he himself assuming responsibility for the results. Either of these two classes of specifications is permissible, and the engineer may choose the one which in his opinion seems best adapted to the character of the work to be done, and the conditions under which it must be prosecuted.

In the third class of specifications, met with more frequently than they should be, the engineer undertakes to prescribe not only the character of the materials to be used and the methods to be pursued, but also the results to be attained. The position thus assumed is illogical, and often unreasonable, and may lead to complications between the engineer and the contractor. If a contractor be required to turn out a product which shall conform to certain standards, he may properly be given much, if not full latitude, as to how the stipulated results shall be secured, and may be held fully responsible for the outcome; if on the other hand the engineer chooses to specify with more or less minuteness the character of the

materials to be used and the methods of construction to be followed, and enforces compliance therewith, it seems fair and just that he should assume responsibility for the results produced, and therefore unfair to hold the contractor to responsibility for consequences arising from the use of materials and methods which he was allowed no choice or latitude in selecting.

In street paving work, of well-known and standard character, the second class of specifications seems preferable for a number of reasons, the leading one being that the time required to develop the good or bad quality of the work must usually extend over a considerable number of years, and the conditions to which the pavement may be subjected in the meantime are likely to vary so widely that it may be very difficult, if not impossible, to prescribe a satisfactory standard of service and endurance. Disputes are therefore liable to arise between the municipality and the contractor as to the latter's liability, or conditions may make it difficult or impossible to hold the contractor to strict account for that liability.

It is believed that in the present state of the art it is entirely practicable to so frame specifications for the materials to be used and the methods to be followed in the construction of street pavements, and to so enforce compliance therewith, that the engineer and the municipality may safely assume responsibility for the quality of the work produced. While it may be true that local conditions sometimes make it very difficult to enforce compliance with specifications, the same conditions are likely to make it at least equally difficult to secure effective responsibility on the part of the contractor for any long-period guarantee of the work done by him; and the contractor who negligently or purposely violates the specifications during construction is not likely to be more faithful or scrupulous in living up to any guarantees he may make with regard to the future, even where the terms and conditions of such guarantees may be clearly defined and indisputable. The writer has discussed the subject of time guarantees as applied to street pavements pretty fully in his book, "Municipal Public Works," and the above brief statement seems all that is necessary here.

In conformity with this view of the matter, the following specifications aim to set out as definitely and clearly as practicable the requirements for the construction of good pavements of the several standard kinds, and it is assumed that the engineer will be able to, and will enforce them.

It is, however, not infrequently the case that circumstances will compel the engineer to provide for the construction of new kinds of pavement, the value and usefulness of which have not been determined, and for which experience has not furnished the necessary data to enable him to prepare adequate specifications. In such cases the wisest course to follow is to specify results only, safeguarding the interests of the Municipality as fully as possible, and throwing upon the promoter or contractor full responsibility for the materials used, the skillful construction of the work, and the utility of the

product. A proposed form for a general specification of this character will be found at the end of the set.

No attempt has been made to submit specifications for proprietary or patented pavements, or those composed wholly or in part of materials which are patented or protected by trade-marks. The owners or contractors engaged in constructing these pavements, often, if not usually, claim the right to dictate the specifications under which the work shall be done, and the municipal engineer who is called upon to construct such pavements, must, in each case, determine whether the specifications offered are adequate and satisfactory. In many cases the form of general specifications for "untried or experimental pavements" given herein may appropriately be used.

The engineer is, in common with all men, fallible, and he can hardly hope, in the preparation of specifications, to make them perfect; to cover every item and particular; or to escape some ambiguities of expression, and some degree of indefiniteness. The writer can only claim that he has aimed, in the light of a considerable experience, to set out as fully and definitely as practicable the requirements for the proper construction of high-class street pavements, and has endeavored to avoid loose or obscure terms and expressions. The ideal specification is one that furnishes a wholly sufficient guide to the accomplishment of the desired purpose; that provides for every possible contingency which may arise, and is couched in language which not only means exactly what it was intended to mean, but is incapable of any other interpretation. It is needless to say that no example of such a specification can be instanced as a model.

It has been the aim to make these specifications fair and just to the contractor; that is, to require of him no impracticable or indefinite service, or the assumption by him of risks other than those fairly involved in the conduct of the work.

If the plans and specifications for any work which a contractor bids upon are so full, specific and clear, that he may know exactly what he will be expected to do, and if they do not require him to assume unusual chances and risks, he may intelligently name prices which he believes will compensate him for the service. Having done so, his proposal having been accepted, and a contract entered into accordingly, the engineer and the municipality have a right both in law and equity to demand that he will do exactly and fully what he has contracted to do. No excuses on his part can be valid and none should be accepted. He may in all fairness and justness be required to "toe the mark" strictly. To the neglect to recognize and enforce these principles is chargeable the greater part of the poor and unsatisfactory work so common in street pavement work in our cities. Unexpected contingencies may, of course, arise where some changes and concessions may be proper and just, but these should be, and usually are, very rare. On the other hand, sweeping general clauses in contracts and specifications intended to catch the

contractor "goin' or comin'," unnecessarily stringent stipulations which were never intended to be strictly enforced, but were put into the specifications with the idea that they would help hold the contractor up to a high standard, and "one-sided" contracts intended to give the municipality an unfair advantage over the contractor, are as inadvisable in policy as they are wrong in principle. Nothing should be put in a specification that is not clearly essential to secure the results aimed at, and, this having been done, every requirement should be enforced. The existence in specifications of requirements that are not intended to be enforced, gives the contractor a pretext for neglecting others that may be important.

In these specifications will be found a number of details that are often not regarded as important and which, when found in paving specifications, the contractor is frequently allowed to ignore. In the writer's opinion, based upon his experience in street paving, every one of these requirements are essential to the production of high-class work, which, it is hardly necessary to argue, is, in the end, the most economical work from the standpoint of the municipality.

It may be argued that the adoption and enforcement of these specifications would have the effect of raising prices. In many cases this would doubtless prove true. Contractors are entitled to a fair and reasonable compensation for their services. It is admitted that in some cities the prevailing prices for some kinds of pavements are below the actual cost of the work if it were done in a proper manner, conforming strictly to the specifications. Illogical as it undoubtedly is, the low price at which work is taken is sometimes considered a sufficient reason for accepting work below standard. The consequence is that bidders not only count upon concessions and lax enforcement of the specifications, but bid lower and lower, expecting that further concessions will enable them to get out with an undeserved profit. This is one of the most serious evils in the paving business to-day, and the highest public interests demand a thorough reform. Low first cost, desirable as it may be, is the poorest economy if it be secured at the sacrifice of the quality of the work. If one pavement costs twenty per cent. more than another, but renders forty per cent. more service, it is obviously the cheaper of the two.

Contractors are prone to contend that this or that provision in a specification is unusual, unnecessary or unfair. In dealing with them the engineer should bear in mind that no requirement of a specification which is clearly and definitely stated so that the bidder may understand exactly what it means and what he will be expected to do, and may frame his prices accordingly, can be unreasonable or unfair to the contractor. Unusual or unnecessary requirements may result in unwarrantably increasing the cost of the work, and this may raise a question between the engineer and the municipality employing him, but it can furnish no occasion for questions of fairness or unfairness between the contractor and the engineer.

NEW YORK, Dec. 27, 1906.

SPECIFICATIONS.

For Grading and Paving, or Repaving

with Pavement
on a Foundation, the Roadway
of
Street, from
to
together with all work incidental thereto.

General Description of Work.

The work embraced in and to be done under this contract consists of grading the entire street from curb to curb between the limits named, including the removal or readjustment of the pavement now on the roadway, setting and resetting curbing, laying or relaying sidewalks where required, furnishing all new material and performing all the labor required for paving the roadway, together with all incidental work necessary to complete the whole in a proper manner, in accordance with the contract, the plans on file in the office of the City Engineer, these Specifications and the instructions of the City Engineer, herein referred to as the Engineer, or his authorized agents.

References.

The numbered divisions of these specifications are herein designated as "sections," each being referred to by the number standing at its beginning.

The plans and drawings relating to this work, on file in the office of the City Engineer are designated as.....
.....

Authority.

1. Wherever, in these specifications, the words, the City, are used, they shall be understood to refer to the duly constituted municipal government of the city of.....
.....
or its authorized agents, acting within the authority specifically conferred upon them by the said municipal government.*

Wherever, in these specifications, the words, the Engineer, shall be used, they shall be understood to refer to the City Engineer

*In specifications to be used in any particular city the official name of the city government, as the City Council, the Commissioners of Public Works, etc., should be used instead of this general designation.

of said city, or his deputies or assistants acting within the authority conferred upon them by the City Engineer.

But no agent of the city shall have power to revoke, alter, enlarge or relax the stipulations or requirements of these specifications, except in so far as such authority may be specifically conferred in or by the specifications themselves, without the formal authorization so to do, conferred by ordinance, resolution or other usual official action of the city.*

Interpretation.

2. In case of any actual or alleged disagreement or discrepancy between the contract, these specifications, and the plans for the work on file in the office of the Engineer, the language and provisions of the contract shall take precedence and prevail; and the Engineer shall determine in each case whether the specifications or the plans shall be followed.

Quality of Material and Work.

3. The judgment and decision of the Engineer as to whether the materials supplied and the work done under this contract comply with the requirements of these specifications, shall be conclusive and final. No material shall be used in the work until it has been examined and approved by the Engineer, or his authorized agents. All rejected material must be promptly removed from the work and replaced with that which is acceptable to the Engineer, and all improper or defective work must be corrected, and, if necessary, removed and reconstructed so as to comply with these specifications and the instructions of the Engineer.

Inspection.

4. The Engineer may provide for the inspection, by assistants and inspectors under his direction, of all materials used and all work done under this contract. Such inspection may extend to all or any part of the work, and to the preparation or manufacture of materials to be used, whether within the limits of the work on the street, or at any other place. The Engineer and his inspectors shall have free access to all parts of the work, including mines, quarries, manufacturing, or other places where any part of the materials to be used is procured, manufactured or prepared. The Contractor shall furnish the Engineer all information relating to the work and the material therefor which the Engineer may deem necessary or pertinent, and with such samples of materials as may be required. The Contractor shall, at his expense, supply inspectors with such labor and assistance as may be necessary in the handling of materials for proper inspection. Inspectors shall have authority to reject defective material and to suspend any work that is being improperly done,

*Such a proviso as this seems proper in justice to both the city engineer and the contractor; the former should not be held responsible for the acts of his assistants when they transcend the authority conferred upon them, and the latter should be put upon his guard with reference to requirements which he is not satisfied are sanctioned or approved by the city engineer.

subject to the final decision of the Engineer. Inspectors shall have no authority to permit deviations from, or to relax any of the provisions of these specifications without the written permission or instruction of the Engineer; nor to delay the Contractor by failure to inspect materials and work with reasonable promptness.

The payment of any compensation, whatever may be its character or form, or the giving of any gratuity, or the granting of any valuable favor, by the Contractor to any inspector, directly or indirectly, is strictly prohibited, and any such act on the part of the Contractor will constitute a violation of these specifications.*

Injuries to Persons and Property.

5. The Contractor shall be held alone responsible for all injuries to persons, and for all damages to the property of the city or others, caused by or resulting from the negligence of himself, his employees or agents, during the progress of, or connected with the prosecution of the work, whether within the limits of the work, or elsewhere. He must restore all injured property, including sidewalks, curbing, sodding, pipes, conduits, sewers and other public or private property to a condition as good as it was when he entered upon the work.

Sanitary Conveniences; Nuisances.

6. The Contractor shall provide all necessary privy accommodations for the use of his employees on the street, and shall maintain the same in a clean and sanitary condition. He shall not create nor permit any nuisance to the public or to residents in the vicinity of the work.

Public Convenience.

7. No material, or other obstruction shall be placed within five feet of fire hydrants, which must be at all times readily accessible to the Fire Department.

During the progress of the work the convenience of the public and of the residents along the street must be provided for as far as practicable. Convenient access to driveways, houses and buildings along the street must be maintained wherever possible. Temporary approaches to and crossings of intersecting streets and sidewalks must be provided and kept in good condition, wherever practicable.

Barriers, Lights, Watchmen.

8. The Contractor shall provide and maintain such fences, barriers, "street closed" signs, red lights, and watchmen as may be necessary to prevent avoidable accidents to residents and to the public.

*It may be objected that this requirement is unusual and unnecessary, since such practices are recognized as wrong, and as presumptive of fraud and malpractice on the part both of the contractor and the inspector. It cannot, however, be denied that in many cities such means are employed by contractors to unduly influence the action of inspectors and that not infrequently the latter not only accept, but persistently demand, valuable considerations from the contractor. Silence of the specifications on this point cannot, of course, be construed into consent, but there is no good reason for the silence. There should be left no excuse for misconception of the position of the city or of the engineer upon this point.

Disorderly Employees.

9. Disorderly, intemperate, or incompetent persons must not be employed, retained, or allowed upon the work. Foremen or workmen who neglect or refuse to comply with the instructions of the Engineer, shall, at his request, be promptly discharged, and shall not thereafter be re-employed without his consent.

Order and Progress of Doing Work.

10. The work under this contract shall be prosecuted at as many different points, at such times, and in such sections along the line of the work, and with such forces as the Engineer may from time to time deem necessary, and direct, to secure its completion within the contract time. Not more than one thousand (1,000) linear feet of the street shall be torn up, obstructed or closed to travel at any one time without the written permission of the Engineer. Completed portions of the pavement shall be opened to travel as directed by the Engineer, but such opening shall not be construed as an acceptance by the City of the work done. Where thus opened to public travel by the direction of the Engineer, the Contractor will not be held responsible for injuries to the work caused by such travel or public use, pending the final completion and acceptance of the whole work.

Measurement and Estimates.

11. Final estimates will be based upon the actual quantities of completed and accepted work, customary or conventional methods of measurement and computation to the contrary notwithstanding.

Grade and Contour of Pavement.

12. Roadway pavements shall be laid to such grades, crown and contour of surface as the plans may show or the Engineer may direct, and the surface of the completed pavement shall conform accurately to such grades, crown and contour. The designed surface of the completed pavement shall be considered as the datum or plane of reference in fixing the location or level of the sub-grade, of the pavement foundation, and of structures connected therewith. It will be hereafter referred to in these specifications as "The pavement datum."

City Monuments or Stakes.

13. The Contractor must carefully protect from disturbance or injury all city monuments, stakes and benchmarks, and shall not excavate nearer than five feet to any of them without the permission of the Engineer; or until they have been removed, witnessed, or otherwise disposed of by the Engineer.

Old Material.

14. All material or structures removed from the street and not required for the new construction, but which the city may desire to reserve, shall be delivered and neatly piled up in a corporation yard or elsewhere, by the Contractor, as the Engineer may direct. Such reserved material shall be considered in the custody of the

Contractor until delivered at the place designated, and he will be held responsible for its care and protection, and must make good any losses occasioned by damage, theft, or misappropriation while it is on the street or en route to the place of storage. If the Contractor shall be required to haul such reserved material more than one-half mile, he shall be paid a reasonable price, to be agreed upon in advance, for the haul exceeding that distance.

Material taken from the work which is to be used in the new construction shall be compactly piled where it will least obstruct the sidewalks or adjoining sections of the street, and properly protected by the Contractor until it is required for use.

All old material removed from the work, including the material excavated in preparing the sub-grade, not reserved by the City nor to be used again in the work, shall belong to the Contractor and must be removed by him from the street as promptly as possible. It must not be placed on the sidewalks or adjacent streets, nor on any other street or property belonging to the City, nor on the property of private owners, without the written consent of the Engineer, or the owner of the property.

Storage of New Material.

15. The material for construction when brought upon the street shall be neatly piled so as to cause as little obstruction to travel as possible, and so that it may be conveniently inspected.

Rebuilding and Adjusting Street Structures.

16. Catch basins, manhole, sewer and water frames and covers, sewer inlets, water pipes and other conduits, belonging to the City and within the limits of the work, shall, if necessary, be reset to the new lines and grades of the street and for this purpose good brick masonry of the original thickness, laid in Portland cement mortar shall be used. Great care must be taken to set all such structures as project through the pavement exactly to the grade and contour of the new street surface, and any defects in the conformity of such structures to the pavement datum, discovered at the time, or during the progress of the work, or during the guaranty period, stipulated in Sec. 108, shall be promptly remedied by the Contractor.

Noiseless Manhole Covers.

17. Asphalt-filled noiseless covers, complete, for water and sewer manholes, of approved design, shall be furnished and set by the Contractor wherever directed by the Engineer. They shall be made according to general plans and details furnished by the Engineer, and of such dimensions as to properly fit their frames.

Clean Sidewalks.

18. During the progress of the work, the sidewalks and portions of the street adjoining the work, or in its vicinity, must not be obstructed or littered more than may be absolutely necessary, and the adjacent sidewalks must be kept clean.

Final Cleaning Up.

19. Immediately after the completion of the work or any consecutive portion of it, the Contractor shall remove from it all unused material, refuse and dirt placed by him on, or in the vicinity of the work, or resulting from its prosecution, and restore the street to a condition as clean as before the work was begun; and the new pavement shall be properly cleaned.

Incidental Work at Contractor's Expense.

20. All the work to be done by the Contractor, specified and enumerated in Sections 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18 and 19, as well as any minor details of work not specifically mentioned in the specifications, but obviously necessary for the proper completion of the work, shall be considered as incidental, and as being a part of and included with the work for which prices are named in the contract. The Contractor will not be entitled to any extra or additional compensation therefor.

Extra Work.

21. The City may require the Contractor to furnish such additional materials and to do such additional work, not provided for in the contract and these specifications, but which may be found necessary or pertinent to the proper prosecution and completion of the work embraced in the contract, at prices to be agreed upon in writing, in advance. But no work other than that included in the contract and these specifications and which is covered by and to be paid for at the prices named in the contract, shall be done by the Contractor except upon a written order from the Engineer. In the absence of such written order from the Engineer the Contractor will not be entitled to payment for any such additional or extra work.

Curbing to be Completed in Advance.

22. The setting of all new curbing and guttering and the redressing, resetting or readjustment of all old curbing must be completed at least 100 feet in advance of the construction of the street foundation.

Preparing the Sub-Grade.

23. The whole area to be occupied by the pavement and its foundation shall be excavated to a sub-grade at such a depth that after being compacted by the roller, the surface will be inches below the pavement datum, and truly parallel thereto. In excavating, the earth must not be disturbed below the sub-grade. Plowing will not be permitted where the depth of earth to be removed is less than six (6) inches, and in no case must the plow be allowed to penetrate to within less than one inch of the sub-grade. Places that are found to be loose, or soft, or composed of unsuitable material, below sub-grade, must be dug out and refilled with sand, or other material as good as the average of that found on the street. After the excavation is completed and the surface neatly trimmed, the whole area shall be well compacted by rolling with a roller

weighing not less than five tons. Areas inaccessible to the roller shall be rammed until they are as well compacted as the rolled surface. When the rolling is completed the surface must be nowhere more than three-fourths inch below, nor more than three-eighths inch above the true sub-grade. If, after the rolling is completed and before the pavement foundation is laid, the surface shall become disturbed in any way, it must be replaced and properly compacted.

Where the natural surface of the ground shall be below the sub-grade, or shall become so by the removal of old pavement or other structures, it must be filled to the sub-grade in layers not exceeding five inches in depth, and each layer shall be thoroughly rolled or rammed before the next layer is placed upon it, and when the filling is completed the filled area must be properly trimmed and compacted by rolling or ramming to the true sub-grade, as in excavation. The material excavated from the street may be used for such filling, provided it be of suitable quality. Where it cannot be thus procured from the street it must be obtained by the Contractor elsewhere, in which case the actual quantity so obtained, measured after it is compacted in the street, will be paid for at the contract price for "earth filling." The price bid for "earth excavation" will be paid for all material excavated above the sub-grade, measured in place on the street, which price includes the cost of disposing of the excavated material, whether as waste or filling, and of trimming and rolling or ramming the sub-grade, and of making it ready for the pavement foundation.

Where the soil composing the sub-foundation is found to be wet or "springy," a system of soft tile drains, discharging into the street drainage system, shall be constructed by the Contractor, as directed by the Engineer. The tile shall be laid in trenches about one foot wide and from one to two feet deep. After the tile is in place the trenches shall be filled with compacted crushed stone or gravel. The tile will be paid for at the contract prices for the same, which shall include the cost of excavating and filling the trenches.

PAVEMENT FOUNDATION.

24. Pavement foundation shall consist of hydraulic concrete, or of old pavement stone relaid, or of broken stone or gravel, as may be herein specified, constructed upon the sub-grade.*

*In the great majority of cases the most satisfactory and, in the end, the most economical foundation for a pavement is hydraulic cement concrete. Old paving block foundation, if constructed as specified in Sect. 36, will give results equally as satisfactory, but if a fair market exists for the blocks taken up from the street, it will usually be found more economical to sell them and construct a concrete foundation for the new pavement. Broken stone or gravel foundations may serve the purpose fairly well upon a street of light travel, but it should never be used on streets of considerable or heavy travel. Its lower first cost is the only thing in its favor, but this will, in nearly every case, be more than offset by the better service and greater durability of the pavement, even on streets of light travel, if laid upon an adequate hydraulic concrete foundation. Proper repairs to pavement surfaces cut into for pipe work, etc., are difficult to make and hardly ever satisfactory over broken stone foundation for the reason that the lack of cohesion in the material allows it to loosen or crumble away

CONCRETE FOUNDATION.

Concrete.

25. Concrete shall be composed of Portland cement, sand, broken stone and water.

Portland Cement.*

26. Portland cement shall be defined as the pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than three per cent. has been made subsequent to calcination.

Specific Gravity. The specific gravity of the dry cement at a temperature of two hundred and twelve (212) degrees F. shall not be less than 3.10.

Fineness. It shall be pulverized to such fineness that not more than eight (8) per cent. shall fail to pass a number one hundred (100) sieve and not more than twenty-five (25) per cent. shall fail to pass a number two hundred (200) sieve.

Time of Setting. At the temperature of sixty (60) degrees F. mortar made of neat cement shall not begin to set in less than thirty

from under the edge of the pavement surface, and it is difficult to restore it to its original solidity and strength. The first cost saved by its use is usually not great; for whenever its use would be permissible at all, a comparatively thin and lean concrete would give better results, at a very slight increase in cost. To illustrate: On a suburban street with light travel a concrete foundation four inches in thickness, the concrete made with Portland cement in the ratio of 1 cement, 4 sand and 8 stone, would be stronger and in every way better than a foundation eight inches in depth of broken stone. At the usual prices of materials and labor, the former may cost about \$0.46 per sq. yd., and the latter about \$0.40 per sq. yd.; but for the latter there would be required 1-9 cu. yd. more sub-foundation excavation, worth about four cents, so that the equivalent cost would be \$0.44 per sq. yd. The difference, two cents per sq. yd., is insignificant when compared with the greater value, better service, and greater durability of a pavement on the concrete foundation. It is sometimes held that the broken stone foundation provides necessary sub-drainage. But all the standard pavements are, or soon become, impermeable to water from the surface, and seepage from the sub-foundation can be better taken care of by the sub-drainage specified in Sect. 23, which should usually cost not more than five cents per square yard of the pavement; and if drainage be required, these sub-drains should be used even with the broken stone foundation.

The practice of laying pavement surfaces, particularly those of asphalt, upon a foundation of old stone blocks, carelessly reset, with the joints unfilled with mortar, (common in a few cities) is all wrong and should never be resorted to. The integrity and durability of an asphalt pavement depends largely upon the strength and rigidity of its foundation; to lay an asphalt surface, however good, over such an old block foundation, is an inexcusable waste of money.

Old stone block and cobble-stone pavements that have become solidified in place by long travel over them, make a good foundation for asphalt or other pavements, provided they can be utilized without taking up or disturbing the old pavement; but such cases occur so rarely that they have not been considered in these specifications.

A thoroughly consolidated old McAdam pavement, if not worn too thin, also makes a very satisfactory pavement foundation if it can be used undisturbed, or by simply trimming off the high points.

Low places, otherwise satisfactory in old pavements to be used for foundation, may be brought to the proper elevation with hydraulic concrete. "Binder" material is usually specified for this purpose in foundations for asphalt pavements, but hydraulic concrete is both better and cheaper.

*The specifications for Portland cement here given are practically those adopted by the "American Society for Testing Materials."

Natural Cement. While these specifications uniformly refer to the use of Portland cement, it is not intended to convey the idea that natural cement concrete is not suitable for pavement foundations; on the contrary, it may be used with entire confidence, as the experience in a large number of cities has proven beyond question. Whether Portland or natural cement shall be used is usually a question of relative cost. At the present very low prices of Portland cement in

(30) minutes, nor set hard in less than one hour, but must set hard within ten (10) hours.

Strength. When thoroughly mixed dry with clean, sharp, moderately coarse sand, in the ratio by weight of one part cement to three parts of sand, and then made into stiff mortar, briquets made from this mortar and exposed for one day to moist air and immersed in water for the balance of the periods named below, shall develop a tensile strength per square inch not less than the following:

In seven days.....175 pounds.

In twenty-eight days.....250 pounds.

Constancy of Volume. When subjected to standard tests for constancy of volume, the cement shall show no tendency to swell or crack.

Composition. The cement shall not contain more than one and three-fourths (1.75) per cent. of anhydrous sulphuric acid, nor more than four (4) per cent. of magnesia.

Tests. Cement tests shall be conducted in accordance with the methods recommended by the "Committee on Uniform Tests of Cement" of the American Society of Civil Engineers.

Conditions. All cement shall be supplied in original packages with the brand of the manufacturer marked on each package. It shall be protected during transportation from rain and moisture. It shall be delivered upon the work at least ten (10) days (exclusive of Sundays and holidays) before it is to be used, in order to allow of proper inspection, and the contractor shall furnish all necessary facilities for such inspection. Brands of cement without established good reputation, or not heretofore used in the City ofmay be rejected; or they will be accepted only after they satisfactorily pass the 28-day test. Rejected cement must be at once removed from the street.

Sand.

27. Sand for concrete shall be composed of grains not softer than hard limestone. It shall be moderately coarse and preferably made up of grains of varying size producing a mass with low percentage of voids. It shall not contain, in all, more than five (5) per cent. by volume of clay, loam, mica scales, silt, or other objectionable inorganic matter, nor more than one (1) per cent. of organic matter.

many cities, more strength in pavement foundations can usually be obtained per dollar expended for cement, from Portland than from natural cement. The specifications for natural cement, as adopted by the American Society for Testing Materials differ from those for Portland cement in the following particulars:

The **specific gravity** shall not be less than 2.8.

Fineness. The residue left on a No. 100 sieve shall not exceed 10 per cent., and on a No. 200 sieve shall not exceed 30 per cent.

Setting. It shall not begin to set in less than ten minutes, nor set hard in less than thirty minutes; but shall set hard within three hours.

Tensile Strength (per sq. in.).

Neat. 24 hours in moist air..... 50 to 100 lbs.

7 days (1 day in air, 6 days in water).....100 to 200 lbs.

28 days (1 day in air, 27 days in water).....200 to 300 lbs.

1 part cement, 3 parts sand.

7 days. (1 day in air, 6 days in water)..... 25 to 75 lbs.

28 days. (1 day in air, 27 days in water).....75 to 150 lbs.

Soundness. Standard pats kept in air and in water should remain firm and hard and show no signs of cracking or disintegration.

Broken Stone.

28. Broken stone for concrete shall be of hard and sound limestone or other stone equally hard and durable, broken to a roughly cubical form. It shall be screened through efficient revolving screens, and only such fragments as have passed through circular screen openings two and one-half ($2\frac{1}{2}$) inches in diameter, shall be used. If the crushed dust and fine fragments be not screened out, the stone must be so handled that the fine material will be evenly distributed through the mass when it reaches the concrete platform or mixer.*

Water.

29. Water used for concrete shall be fresh, and reasonably clear.

Care and Handling of Concrete Material.

30. Cement must not be allowed to become wet or damp. It shall be stored until used, whether in storehouses or on the street, so that no part of the packages shall be nearer than four (4) inches to the ground or pavement, and shall be effectually covered so that rain cannot reach it. Sand and stone, if stored on the street, shall be on lumber floors.† The stone shall be thoroughly wetted a sufficient time before being placed in the concrete to allow any surplus water to drain away, but shall remain moist when it reaches the concrete platform or mixer.

Ratio of Concrete Materials.

31. Concrete will be composed of one part Portland cementparts of sand and.....parts of broken stone, and the proper quantity of water, all measured by volume.‡ The unit of measurement shall be the barrel of cement which shall be considered as containing four (4) cubic feet. The materials shall each be measured in such manner and with such accuracy that the quantities used will not vary more than seven (7) per cent. from the quantities required in the ratio named above for each batch of concrete.

*The frequent requirement that the fine material shall be screened out, is not necessary or advisable. Experiments and experience have shown conclusively that unless an unusual amount of fine material and "dust" be present, or unless this fine material be allowed to separate and aggregate in masses by itself, the resulting concrete is improved rather than deteriorated by its presence.

Where there is an unusual excess of "dust" in the crushed stone, the quantity of sand used in the concrete should be decreased accordingly.

†Many specifications do not require this and in a number of cities where the specifications do require it, contractors habitually neglect to comply. When stone and sand are deposited directly upon the earth, it is very difficult to avoid taking up earth and mud with the materials, particularly when the street is wet and muddy. Lumps of soil and debris unquestionably injure the concrete. The cost of providing a lumber floor is comparatively small, as the plank may be used over and over again. Specifications should, therefore, contain this requirement and it should be enforced.

‡The ratios of the materials may appropriately be varied with the strength and soundness of the sub-foundation, the amount of travel on the street, and with the thickness of foundation it is proposed to use. Where good materials are used and the work is properly done, a 1:3:5 concrete six inches thick is sufficient for streets of the heaviest travel. For streets of light travel a 1:5:9 concrete will usually give entirely satisfactory results. The most economical thickness for a concrete foundation is an important consideration. The strength of concrete may be said to increase, within usual limits of practice, with the ratio of cement in it. The strength of concrete beams or slabs

Mixing Concrete.

32. If mixed by hand, concrete shall be mixed on platforms of iron or wood of sufficient size to admit of proper manipulation of the concrete. The sand shall be first spread evenly over the platform and the cement evenly distributed over the sand. These two materials shall then be mixed dry until a uniform and homogeneous mixture is secured. Sufficient water shall then be added and the mixing resumed and continued until a mortar of uniform consistency and texture is produced and distributed in an even layer over the platform. The stone shall then be distributed over the mortar and mixed therewith until the mortar is evenly distributed through the mass and every fragment of stone is well coated with mortar, sufficient additional water being added as the mixing progresses to produce a rather wet, but not sloppy, concrete.* Machine mixing of concrete will be preferred, provided the machine used secures equal accuracy in the ratios of materials and equally as good mixing as prescribed above for hand-mixing. Machine-mixed concrete must be delivered from the machine upon a wood or metal platform and be thence shovelled into place on the street.

Placing the Concrete.

33. Concrete shall be placed on the sub-grade in such a manner as to prevent as far as possible the separation of the mortar from the stone. It shall be evenly distributed in a single horizontal layer of such depth that, after ramming, it will be not less thaninches thick.† Immediately after being so placed it shall be well rammed until a compact mass is produced with its upper surface parallel to andinches below the pavement datum. Depressions that may appear during the ramming

increases in the ratio of the square of their depth. To secure a required amount of strength in a pavement foundation, we may therefore vary the richness of the concrete and the depth of the foundation so as to secure the requisite strength at the least total cost of materials and labor. This will be influenced by the cost of materials and labor in each particular locality.

Within certain workable limits there is no reason why the same principles of proportioning the strength of a pavement foundation to the work required of it should not be applied as are employed in designing other engineering structures.

The practice, usual in many cities, of adopting general specifications requiring a standard thickness of foundation and composition of concrete, and applying these to all streets, regardless of the quantity and character of travel which the pavement is expected to carry, is illogical and often very wasteful. If such a standard foundation is sufficient for the streets of the heaviest travel, it is obviously a sheer waste of money to use it on the suburban streets carrying the lightest travel. It is therefore better in preparing standard specifications for pavement in any city to leave blanks for the ratios of the concrete and for the thickness of the foundation, to be filled in, in each individual case, as the judgment of the engineer may dictate.

While it is important that the foundation of any pavement shall be adequate, it is inexcusable to waste money in providing superfluous strength. For the great majority of suburban streets, carrying but little except the local travel, a foundation four inches thick made of good Portland cement concrete in the ratios of 1:4:3 will prove entirely satisfactory. Hundreds of such streets paved over a foundation of that thickness, made of natural cement concrete in the ratios of 1:2:4 can be cited where the foundation has proved entirely satisfactory.

The character and firmness of the sub-foundation must, of course, be taken into consideration in designing the foundation.

*The routine here described produces better concrete with less expenditure of labor, than the one often followed of putting all the dry materials on the concrete board before any mixing is begun. The writer has proved this from actual records covering a large quantity of work.

†See foot-note (†), page 18.

may be filled with concrete of the same composition as used for the foundation, except that smaller-sized stone shall be used; mortar alone must not be used for this purpose, nor shall the upper surface of the concrete be plastered with mortar.*

Setting of Concrete.

34. After the concrete is completed it shall remain undisturbed until it be firmly set. The time allowed for setting shall not be less than five days, and as much longer as, in the judgment of the Engineer, may be necessary, depending upon the temperature of the weather and the setting qualities of the cement. During this period no hauling or traveling over the concrete must be permitted unless its surface be first protected by a covering of plank. The Contractor shall, if necessary, keep the concrete moist by wetting it, with hose, or otherwise, until twenty-four (24) hours before it is to be covered with the pavement surface.

Measurement of Concrete.

35. Concrete will be measured and computed in cubic yards as found completed on the street, the thickness being taken asinches. The contract price for concrete foundation covers the cost of providing all the materials required, making, placing and ramming the concrete, and keeping it moist for the necessary period.

FOUNDATION OF OLD PAVING STONE.

36. Foundations made of old stone paving blocks shall be constructed as follows:

Upon the sub-grade prepared as specified in Section 23, shall be spread a layer of good sand to an even depth of one and one-half ($1\frac{1}{2}$) inches. The paving blocks, whether taken up from the street to be paved, or brought from other streets or storage yards, shall be cleaned of all adhering earth, dirt and street refuse. The blocks shall then be set on the bed of sand, on edge, perpendicular to the grade, with their long dimension at right angles to the line of the street, in courses composed of stones of the same width, extending entirely across and at right angles to the axis of the street. Stones in adjoining courses shall break joint at least two inches. Joints between courses or stones, or along the curbstones, shall not exceed one inch in width. The stone shall be fitted closely around man-holes or other structures in the street. The stones shall be so set in the bed of sand that after being rammed as hereafter specified, their tops shall be at the proper grade. In street intersections the courses shall be laid at an angle of forty-five (45) degrees with the line of the street if the Engineer shall so direct. After being thus set in place the stone shall be rammed with paving rammers having wooden faces and weighing not less than thirty (30) pounds, so as

*The objections to using mortar for plastering over the concrete are: that it is more costly than concrete; that the two materials may, under certain conditions, separate and the thin mortar surface break up under travel; that, if permitted, the mortar may be used to cover up defective concrete, and that in the case of asphalt pavements the pavement surface is more likely to "shift" on the smooth surface of the mortar than on the rough surface of the concrete.

to force each stone to a good bearing in the sand below, and to bring its top to a uniform grade, parallel to and..... inches below the pavement datum. No stone shall project more than one-fourth ($\frac{1}{4}$) inch above the proper grade, and stones whose tops, after ramming, are more than three-quarters ($\frac{3}{4}$) inch below such grade, shall be raised, additional sand placed under them, and reset and re-rammed to the proper grade and bearing. After the ramming shall have been completed, the joints between the stones shall be filled with mortar. The mortar shall be composed of Portland cement and sand, complying with the specifications for these materials in Sections 26 and 27. One part of cement and three parts of sand, by volume, shall be thoroughly mixed dry, and then made into mortar with a sufficient quantity of water to produce a mortar of such consistency that it will just flow freely into the joints between the stones. All the joints between the stones must be completely filled with this mortar before it has begun to set. The mortar filling shall be brought even with, but not above, the tops of the stones. After the filling is thus completed, the foundation must stand undisturbed until the mortar shall have set firmly, in no case less than five days. The mortar must kept moist during the period allowed for setting.*

Old stone foundation will be measured in square yards, in place after completion, the average depth being taken as..... inches. The contract price includes the cost of handling and cleaning the stone, supplying and placing the bed of sand, setting and ramming the stone, supplying the materials for, making and placing the mortar in the joints and watering the street while the mortar is setting. Where stone is procured from other streets, or from storage yards, the Contractor will be required to load, haul and unload them, and will be allowed for this service a price of..... cents per cubic yard for loading and unloading, plus.....

*See foot-note, p. 15. The cost of filling the joints of old block pavement with mortar or grout is considerable. It will hardly ever be less than 20 cents and may exceed 35 cents per square yard, depending on the volume of joints and the local cost of material and labor. The cost of re-setting and ramming the blocks with proper care will usually be from 10 cents to 12 cents per square yard, so that the cost of the foundation, exclusive of the value of the blocks, may vary from 30 cents to 47 cents per square yard.

As a good concrete foundation 6 inches in depth can be laid for from 70 to 90 cents per square yard, it is obvious that if the old blocks can be sold for as much as the difference between the cost of the old block and the concrete foundation, nothing will be saved by using the old block foundation. In at least one city, asphalt pavement is extensively laid over old stone block foundation relaid in a very careless manner, the joints being filled usually with the old sand or loam found in the street. This practice cannot be too strongly condemned. Asphalt pavement surfaces resting on such a foundation are necessarily short-lived and unsatisfactory. The practice of opening the street to travel for a period after the blocks are relaid and before the asphalt surface is applied, helps, under favorable conditions, to consolidate the foundation, but does not remove the objections to it. If heavy rains intervene, the sub-foundation becomes saturated with water, and its resistance so reduced that the stone blocks settle out of shape, particularly in soft spots, and they are usually hastily raised and reset just before the asphalt surface is applied. The result is an insecure foundation fatal to the durability and usefulness of the pavement.

cents per cubic yard for each one-half mile, or fraction thereof, over which they are hauled by the nearest practicable route, the measurement to be made after the stone is set in the street, without deduction for joints.

Broken-Stone Foundation.

37. The sub-grade for broken-stone foundation shall be prepared as specified in Section 23, except that the rolling may be omitted at the option of the Contractor. The broken or crushed stone shall be of hard, durable stone. The foundation shall be constructed in two courses, as follows:

The broken stone used in the first course shall be of such size that it will all pass through a screen having openings two and one-half ($2\frac{1}{2}$) inches in diameter, and will all be retained on a screen having openings one (1) inch in diameter. This stone shall be evenly spread over the sub-grade to such a thickness that after being thoroughly consolidated by rolling, its upper surface shall be three-fourths inch below, and parallel to the surface of the foundation when completed. It shall then be rolled with a road-roller weighing not less than ten (10) tons until the stone is thoroughly compacted.

The second course, composed of screenings, all of which shall have passed through a screen with openings one inch in diameter, shall then be spread over the first course and well raked into the voids of the first course. It shall then be thoroughly wetted, and shall be rolled with the ten-ton roller until the fine stone is driven into the interstices of the first course and the whole thoroughly consolidated, the wetting being repeated while the rolling continues. Additional screenings shall be added and rolled in where necessary to bring the surface to the proper elevation. When completed, the top surface of the foundation shall be.....inches below, and parallel to the pavement datum. No part of the upper surface of the completed foundation shall project more than one-fourth ($\frac{1}{4}$) inch above, nor shall it be more than one-half ($\frac{1}{2}$) inch below the grade and contour above specified.

Gravel of a quality satisfactory to the Engineer may be substituted for broken stone, with his written consent. If of assorted sizes, such as will compress into a mass having not more than thirty (30) per cent. of voids, the foundation may be constructed in a single layer, graded, watered and rolled, as prescribed above for broken stone.*

Measurement.

38. Broken-stone and gravel foundation will be measured and computed by the cubic yard in the street as completed, without any allowance for consolidation by the roller or for settlement into the

*Where there is a possibility that gravel may be used, the contractor should be asked to name prices for the gravel foundation as well as the stone foundation, since, unless this be done, the change from the one material to the other might be held to be illegal.

sub-grade, the thickness being taken as.....inches. The contract price for it shall cover the cost of supplying the material, placing it on the street, and grading, watering and rolling it.

BITUMINOUS PAVEMENTS.

Classification.

39. Pavements, the wearing surfaces of which are composed of a mineral aggregate cemented together with bitumen, shall be classified as follows:

(a). **Asphalt Pavement:** Composed of an asphaltic cement made from natural asphaltum, refined and tempered, mixed artificially with sand and finely pulverized stone, or other inorganic substance.

(b). **Rock Asphalt Pavement:** Composed of asphaltum combined in a natural state with carbonate of lime or silica in such ratios as to require the addition of little or no other material.

(c). **Block Asphalt Pavement:** .Constructed of compressed paving blocks composed of asphaltic cement, crushed stone and other mineral aggregate.

(d). **Bituminous Concrete:** Composed of asphaltum, or other bitumens artificially mixed with crushed stone, gravel, sand, pulverized carbonate of lime, or other material.

ASPHALT PAVEMENT.*

General.

40. Asphalt pavement surface shall be laid upon a foundation of hydraulic cement concrete, or of stone blocks relaid, over a sub-grade, to be constructed in accordance with Articles 23, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35 and 36.

Asphalt pavement surface shall be constructed in two courses, called the base-course and the surface-course. The base-course may be from one (1) inch to one and one-half ($1\frac{1}{2}$) inches thick, and the surface-course may be from one (1) inch to two (2) inches thick, as shall be hereafter specified.

*The various kinds of asphalt now used for street pavements differ considerably in their physical and chemical properties. This makes it necessary, in preparing general specifications intended to cover the use of any or all the different kinds now recognized as acceptable, to provide greater latitude than would be proper or desirable if the specifications were intended to apply to any one variety only. To that extent these specifications are defective and open to criticism. So long as it continues to be the policy of cities to admit general and free competition in the use of the several varieties of asphalt under the same general specification, this defect cannot be avoided.

The only remedy for this state of affairs that seems practicable would be for each city to purchase its supply of asphalt, after asking proposals under suitable general specifications, and selecting the kind of asphalt which may seem best and cheapest under the proposals submitted. The contractors for constructing the pavements would then be supplied with asphalt by the city at a stipulated price. The paving specifications could then be prepared with reference to the special qualities of the asphalt to be used.

This plan would possess a number of other obvious advantages. A similar plan is in use in a number of cities and by a number of corporations in supplying hydraulic cement to contractors for the construction of various works.

Notwithstanding the undesirable latitude permitted in the specifications here submitted for asphalt pavement, it is believed that they are a decided improvement upon any now in use, and that, if properly applied and enforced, they will enable the city engineer to intelligently control and direct paving contracts, and to secure satisfactory and uniform results. The typical specification for asphalt pavement heretofore and up to the present time in common use is antiquated, indefinite and unsatisfactory. It is largely a survival of the time when little was known of either the technical or the practical side of the art of constructing asphalt pavements, outside of the promoters and contractors engaged in the business, who consequently dictated largely the specifications for the work. Great advancements and improvements have been made in the technology and the practical construction of this class of pavements in the last decade, but not much change has been made in the usual city specifications for the work, and some of these specifications contain antiquated requirements which, if literally enforced, would prevent the attainment of the best results. Engineers have relied largely upon the presumption that the guarantee clauses in paving contracts would compel the contractors to do the work in the best manner, and have allowed them wide latitude in the conduct of the work.

In the present state of the art there is no longer any good reason why the character of the materials to be used, the methods to be followed and the quality of the work done should not be definitely specified, as is the practice with other kinds of pavement, and with the same satisfactory results.

Crude Asphalt.

41. The cementing element in asphalt pavement shall be prepared from a natural asphalt, possessing the requisite qualities, as hereinafter specified. The crude asphalt, as obtained from the mines or natural deposits shall, if necessary, be properly refined to drive off water and to separate extraneous substances, by melting at a temperature not exceeding four hundred and fifty (450) degrees F. Crude asphalt of the class commonly called "Glance Pitch" and "Iron Pitch," which does not distinctly soften at a temperature of one hundred and eighty-five (185) degrees F., and detached or deteriorated material from otherwise acceptable deposits of asphalt, will not be accepted.

Refined Asphalt.

42. Refined asphalt, other than that prepared from the distillation of asphaltic oils, shall be free from water and shall not contain an injurious quantity of light oils, or extraneous matter, and shall be homogeneous throughout the mass. It shall contain not more than four (4) per cent. of organic matter, and not more than thirty-five (35) per cent. of mineral inorganic matter other than bitumen; and not less than fifty-six (56) per cent. of bitumen soluble in carbon di-sulphide. The bitumen extracted by carbon di-sulphide, when freed from the solvent, shall not be distinctly brittle at a temperature of eighty (80) degrees F. Not less than sixty (60) per cent. of it shall be soluble in Pennsylvania petroleum naphtha of specific gravity seventy-six (76) degrees Baume at a temperature of sixty-five (65) degrees F., and at least ninety-seven (97) per cent. of it shall be soluble in chemically pure carbon tetrachloride. When exposed for seven (7) hours to a temperature of three hundred and twenty-five (325) degrees F., in a shallow dish, the bottom of which is covered with the bitumen to a depth of one-half ($\frac{1}{2}$) inch, the refined asphalt shall lose not more than five (5) per cent. by evaporation.

Asphalts that are injuriously affected, in the pavement, by water (to be determined by the test immediately hereinafter described), shall not be used except under the conditions specified in Section 43. Cylinders made from the surface mixture it is proposed to use, one (1) inch in diameter and two (2) inches long, compressed to a density of two and one-tenth (2.1), when immersed forty-five (45) days in ten (10) times their volume of rain-water, shall retain a sound surface, unchanged and uncorroded by the action of the water.

Asphalts resulting from the distillation of crude asphaltic oils will not be accepted unless the distillation shall have been effected by the use of suitable apparatus, at a temperature not exceeding seven hundred (700) degrees F. The bitumen must not be over-distilled and "cut back" by adding oil. The product, to be acceptable, shall possess the following qualities: It shall melt and flow at a temperature not below one hundred and forty (140) degrees F., but



below a temperature of one hundred and eighty (180) degrees F., and when tested in the standard New York State closed oil-testing apparatus shall not flash at a temperature below four hundred and fifty (450) degrees F. When exposed in a shallow dish, the bottom of which is covered to a depth of one-half ($\frac{1}{2}$) inch with the bitumen, to a temperature of four hundred (400) degrees F., for seven (7) hours, it shall not lose by evaporation more than seven (7) per cent. by weight. Not less than ninety-eight (98) per cent. shall be soluble in cold carbon di-sulphide, and not less than sixty-five (65) per cent., nor more than seventy-five (75) per cent. of the bitumen shall be soluble in cold Pennsylvania naphtha of gravity eighty-eight (88) degrees Baume. Not less than ninety-seven (97) per cent. of the bitumen shall be soluble in carbon tetra-chloride, and it shall not contain more than sixteen (16) per cent. of fixed carbon.*

Bitumens resulting from destructive distillation or from artificial oxidation, and bituminous compounds prepared from oil or oil residuums heated with sulphur or other substances, will not be accepted, nor shall they be mixed with the asphalt used.†

43. Asphalts that are injuriously affected by water, and those whose practical value for making pavements has not been established, in the judgment of the City, by sufficient experience, will not be accepted except under such special bond and guaranty provisions as the City may prescribe.‡

44. Full information as to the source and character of the crude asphalt and the method of refining it shall be furnished to the Engineer and verified by such evidence as he may require.

*There has been much discussion as to the suitability of these oil asphalts, called "residual pitches," for use in making asphalt pavements. When properly prepared from suitable asphaltic oils, so as to comply with the specifications here given, there can be no doubt that good pavements can be made with them. But as they appear on the market, being usually produced at different localities and refineries from crude oils of differing qualities, distilled by somewhat differing methods, and usually at temperatures of from 900 degrees to 1200 degrees, they are likely to vary so greatly in quality as to make their use inadvisable without careful technical inspection. Unless, therefore, the engineer is prepared to make, or to have such inspection made, it is hardly wise or safe to permit their use. They stand, in this respect, upon a footing different from the better-known natural asphalts obtained from large deposits of practically uniform character and quality, where the simpler process of refining is less likely to effect injuriously the chemical quality of the material.

It may be confidently predicted that any of these "residual pitches" which comply with these specifications will, if properly handled, make a good pavement.

†The possibility that some of these compounds, or artificial asphalts, may be suitable for use in pavements is not denied. But in the absence of a fuller knowledge of them than we now have, and in the light of present experience, the only safe course is to reject them.

‡It is not intended here to enter into an extended discussion of the fact that some asphalts are injuriously affected by water, and the bearing which this fact should have upon the selection of an asphalt for pavement purposes. There can be no doubt that modern treatment and methods of construction have tended to diminish but not wholly to prevent the disintegrating effect of water upon pavements made with such asphalt, and if the engineer could be certain that his pavements would be constructed by contractors guided by long experience and the best expert advice, he might perhaps safely disregard this provision. Since in practice he can have no such assurance, the provision is a wise one and it does not involve any serious or material hardship to the contractor.

Softening or Tempering Agent.

45. For softening and tempering refined asphalt, petroleum residuum oil shall be used. It shall be free from water, coke and other impurities. Its specific gravity shall not be below 0.925, nor above 0.958. Its flash test (determined in the standard New York State closed oil-testing apparatus) shall not be under three hundred and fifty (350) degrees F., and when exposed for seven (7) hours to a temperature of three hundred and twenty-five (325) degrees F., in a shallow open dish, the bottom of which is covered by the oil to a depth of one-half ($\frac{1}{2}$) inch, it shall not lose more than seven (7) per cent. by evaporation. It shall not contain more than ten (10) per cent. of paraffine scale.

Sand.

46. A superior quality of sand will be required and this must be secured, if necessary, by the admixture of two or more sands. The sand shall be silicious and so free from organic matter, mica, soft grains, and other impurities, that these shall not aggregate more than two (2) per cent. of the mass. The grains shall, preferably, be moderately "sharp" or angular, and must be of assorted sizes so that the voids in the compacted mass of dry sand shall not exceed thirty-three (33) per cent. A typical sand, to be approximated as closely as practicable, would give the following sieve tests, the sieves being used in the order named:

3 %	of the whole will pass	No. 200 sieve.
15 %	" " " " " "	100 "
18 %	" " " " " "	80 "
30 %	" " " " " "	50 "
10 %	" " " " " "	10 "

and none will fail to pass the No. 10 sieve.*

Pulverized Stone.

47. This may consist of limestone or other sound stone or sand, pulverized to such fineness that the whole will pass the No. 50 sieve, not more than ten (10) per cent. will be retained on the No. 100 sieve, and at least seventy (70) per cent. of it will pass the No. 200 sieve. Portland cement may be partly substituted for pulverized stone, where the Engineer shall so direct.† Portland cement thus used will be paid for at the price bid per barrel for the same, in addition to the price paid per square yard for the pavement surface.

*It is now well recognized that the character and quality of the sand used is one of the most important elements in determining the utility and durability of an asphalt pavement. A satisfactory sand should be insisted on, even if it involves a very considerable increase in the first cost of the work.

While our knowledge of the subject is not complete, experience seems to indicate pretty clearly that a sand of the quality and size-grading here specified as typical, may be depended upon to produce a good pavement.

†The use of Portland cement in surface mixtures to be laid on streets of heavy travel, or those exposed to damp foundations, is very strongly recommended. On streets of the heaviest travel, or where the

Stone for Base-Course.

48. Stone screenings for base-course shall be of crushed, hard, durable stone. The portion used shall all be retained upon a No. 8 sieve, or screen, and shall all pass a screen having square meshes the linear dimensions of which are one-fourth ($\frac{1}{4}$) inch less than the thickness of the base-course.

Asphaltic Paving Cement.

49. The asphaltic paving cement shall be prepared from the crude and refined asphalt specified in Sections 41 and 42, tempered and softened, if necessary, by the addition of petroleum residuum to the consistency and hardness specified below.

The refined asphalt and the petroleum residuum oil shall be mixed and melted together at a temperature not below two hundred and seventy-five (275) degrees F., and thoroughly incorporated by agitation or stirring until a homogeneous cement be produced. The mass shall not be heated to a temperature exceeding three hundred and twenty-five (325) degrees F., and the stirring or agitation shall be continued until the cement be used.

The asphaltic cement, when tested at a temperature of seventy-eight (78) degrees F., in a standard Dow penetration apparatus, shall give a penetration of from forty (40) to eighty (80) degrees, as the Engineer may determine. When a cement of the proper consistency and hardness shall be determined upon and approved by the Engineer, samples of it shall be kept as a standard and all subsequent batches must be made to conform thereto, suitable apparatus and tests being employed to determine the correspondence of each kettle of cement with the standard. The asphaltic cement, when at or slightly below its melting temperature, shall be so viscous that it will draw out into long, fine threads which shall be free from lumps or raggedness, and it shall possess satisfactory cementitious qualities.

Composition and Preparation of Asphalt Surface Mixture.

50. The surface course shall be composed of the materials specified in Sections 41, 42, 43, 44, 45, 46, 47 and 49, mixed in such ratios by weight as the Engineer may direct or approve. A typical mixture will contain:

Sand.....100.0 lbs.

Pulverized mineral matter passing No.200 screen,

including that found in the paving cement.. 17.5 "

^ Pure bitumen (in paving cement)..... 13.5 "

But the quantities of pulverized stone and of asphaltic cement shall be varied as may be found necessary or desirable by the Engineer to suit the purity of the asphaltic cement, the character of the sand,

pavement will be exposed to unfavorable conditions of dampness, particularly if the pulverized stone is not very finely ground, the Portland cement may constitute ten per cent. of the pulverized material, or "dust," as it is commonly called. Ordinarily from five to seven per cent. may be used to advantage on all streets of comparatively heavy travel.

the climatic conditions, and the varying quantity and character of travel on the street to be paved; and Portland cement may be substituted partly or wholly for the pulverized stone, when directed by the Engineer. The surface-course mixture shall be submitted to the Engineer and approved by him before any is laid upon the street.

The mixing shall be accomplished in a mechanical mixing apparatus capable of rapidly and effectually incorporating the materials together, and each batch must remain in the mixer a sufficient length of time to effect a perfect mixture. The sand shall be separately heated and shall reach the mixing apparatus at a temperature not above three hundred and twenty-five (325) degrees F. The pulverized stone shall be at such a temperature that when mixed with the sand the temperature of the mixed mass shall not be above three hundred and twenty-five (325) degrees F., nor below three hundred and ten (310) degrees F. The sand shall be first placed in the mixer, followed by the pulverized stone, and these two materials shall be thoroughly mixed together before the asphaltic cement is added. The asphaltic cement at a temperature not above three hundred and twenty-five (325) degrees, nor below three hundred (300) F. shall then be added in such a way as to evenly distribute it over the sand and pulverized stone, and the mixing continued until the materials are thoroughly incorporated into a perfectly uniform and homogeneous mass, with the grains of sand completely covered with cement. Suitable thermometers shall be constantly used to determine the temperatures specified herein. Great care must be taken to accurately weigh and proportion the materials charged into the mixer.*

Composition of Base-Course.

51. The base-course shall be composed of the crushed stone specified in Section 48, mixed with the asphaltic cement, sand and pulverized stone specified in Sections 49, 46 and 47, but the asphaltic cement shall give a penetration with the Dow apparatus of from seventy (70) to eighty (80) degrees, as the Engineer may direct.

A typical base-course mixture will be composed as follows:

Crushed stone.....	100	lbs.
Sand	42	"
Pure bitumen (in asphaltic cement).....	7	"
Pulverized stone.....	7½	"

But the mixture shall be such that when placed on the street and compressed by the roller the mass shall be dense and the voids in

*It should be noted, in a general way, that there is quite a difference in the temperature to which different asphalts may be safely subjected.

Trinidad asphalt will not be injured by the higher range of temperatures named in these specifications, while Bermudez and some other asphalts should be worked at as nearly as possible to the lower range of temperatures named. The relative amount of loss of the different asphalts when exposed for seven hours to the temperature of 325 degrees (sect. 42) will supply a rough practical guide as to the temperature permissible—the greater the loss, the closer should the lower range of temperatures be adhered to.

the stone completely filled; and to accomplish this the quantity of crushed stone used in the mixture may be increased or decreased, as the volume of its voids may require, in order that they may be completely filled.*

Mixing the Base-Course.

52. The materials for the base-course shall be mixed in the same general manner as prescribed for the surface course (Sect. 50), the crushed stone being delivered first in the mixer. The temperature of the materials being not above three hundred and twenty-five (325) degrees F., nor below three hundred (300) degrees F.

Laying Asphalt Pavement.

53. Asphalt pavement must not be laid except when the surface upon which it is to be placed is dry; nor when the temperature of the air is below thirty-two (32) degrees F., or if a strong wind prevails, when the temperature of the air is below forty (40) degrees F.

The pavement mixture, whether for base- or surface-course, shall be taken to the street as soon after it leaves the mixer as practicable. When the temperature of the air is below eighty (80) degrees F., the loaded vehicles conveying the mixture to the street shall be covered by canvas covers to prevent the escape of heat. When unloaded upon the street, the temperature of the mass should not be below two hundred and sixty (260) degrees F., and any load or portions of a load found under two hundred and forty (240) degrees F. must be rejected. After being unloaded on the street, the mixture must be shovelled into place in such a manner that the whole of it will be moved from the pile into which it was unloaded.

Laying the Base-Course.

54. The base-course will have an average thickness of one and one-quarter ($1\frac{1}{4}$) inches after compression. It shall be laid directly upon the pavement foundation, which must be free from all loose fragments and rubbish and be swept clean in advance of the application of the base-course. The base-course mixture shall be spread upon the foundation and evenly and regularly graded to such a depth that after compression by the roller its surface will beinches below, and truly parallel to, the pavement datum.

Great care must be taken in handling, spreading and grading the mixture to maintain the uniform admixture of the crushed stone throughout the mass. The rakes used must have tines wide apart, and the back of the rake must be principally used for grading. Immediately after being graded, and while still hot, the base-course

*The open base course, or "binder," composed only of crushed stone, coated with pitch or asphaltic cement, extensively and almost exclusively used up to a recent date, is no longer advocated by the best authorities on asphalt pavements. The aim is now to make the base course as dense and strong as the surface course.

shall be rolled with a ten-ton asphalt roller, the rolling being continued until no further compression takes place.

The base-course must not be laid more than one day's work in advance of the surface.

When the base-course is completed it must present a uniform appearance and texture over the whole surface, which must conform so truly to the designed grade and contour that a twelve-foot template, when applied, will show no departure from the true surface greater than one-quarter ($\frac{1}{4}$) inch.

Laying the Surface-Course.

55. In delivering the surface-course mixture upon the base-course, care must be taken not to break or disturb the latter. Any breaks made in the base-course must be so repaired, before the surface course is spread, as to be equal in density and surface to the adjoining base.

Before the surface-course is spread the base-course must be thoroughly cleaned and all rubbish, loose material and street dirt removed.

The material for the surface-course shall be so evenly spread and graded with asphalt rakes that after it is properly compacted by rolling, the surface will coincide with the pavement datum within the limits named below. In grading the material, all lumps must be broken up and the whole reduced to a finely comminuted mass of equal density throughout. Directly after being so graded it shall be rolled with a hand-roller, or light steam-roller, to partly compress the material, and, when so directed by the Engineer, the surface shall then be ironed with smoothing irons heated to a temperature that will melt, but will not burn, the asphaltic cement. A thin layer of hydraulic cement, just sufficient to prevent adhesion between the material and the roller, shall then be swept over the surface, which shall at once be thoroughly rolled with a ten-ton asphalt roller until the material shall be thoroughly compressed and its surface is brought to the exact grade and contour designed for the street surface. The work of the ten-ton steam-roller must begin before the material has cooled below two hundred (200) degrees F., and be continued until the roller makes no further impression upon the surface. The first course of the heavy rolling shall be parallel to the street, after which it should be diagonally rolled, and also cross-rolled if the width of the street permits.* Any portions of the surface not accessible to the roller shall be rammed with hot rammers until compacted equally with the rolled portion. When completed, the surface shall have an average thickness ofinches and must be so free from waves or irregu-

*The importance of proper and thorough rolling is not usually fully appreciated, and this part of the work is often shirked by the contractor. Not only should the heavy roller be at work as soon as the material will bear it, but the roller should, when work is progressing regularly, be kept at work all the time. It is a safe motto that the rolling can not be overdone.

larities that a template not less than twelve feet long, when applied to the street surface shall nowhere show a divergence from the designed true surface of more than three-sixteenths ($\frac{3}{16}$) inch, and a template sixteen (16) feet long applied to the gutters shall show no divergence from the true gutter grade greater than one-eighth ($\frac{1}{8}$) inch.

Before the surface-course is placed, all exposed surfaces of curbs, crosswalks, manholes, etc., with which the surface-course will be in contact, must be well painted with hot paving cement or approved pitch. The street shall not be opened to travel until the pavement has become cold and hard.

Street Railroad Tracks.

56. Where railroad tracks exist on the streets, the sub-grade and the pavement foundation shall extend under the tracks, uninterrupted except by the ties and other structures connected with the track. Where concrete foundation is used, special care must be taken with the concrete directly under or around the rails, and concrete made of fine crushed stone and a higher ratio of cement and sand may be required in contact with the rail. The concrete must be thoroughly tamped under and against the rail.

The asphalt surface shall be laid directly against the rails, which, if their temperature be under fifty (50) degrees F., shall be heated by suitable appliances to a temperature of, or above, sixty (60) degrees F. immediately before the asphalt material is placed around the rail. The hot asphalt material must be thoroughly tamped against and along the rail and under any projecting portions of it, and the surface of the pavement must be even with, or slightly (not more than one-eighth ($\frac{1}{8}$) inch) above the top of the rail. Slot-rails will be treated in the same manner, subject to such modifications as their forms may necessitate.*

Plant.

57. The plant for making asphalt paving mixtures must be of approved modern design, adapted to do the work properly, and equipped with efficient machinery. It shall be of sufficient capacity to turn out at least twelve hundred square yards of pavement surface daily without crowding. Weighing and measuring devices shall be accurate and adapted to the purpose, and must be frequently tested and adjusted. Each plant must be supplied with the apparatus necessary to make all determinations and tests required at the plant to properly conduct the work in accordance with these specifications. Steam-rollers must be properly balanced and the rolling surface must be true and smooth. All the street tools used must be of approved kind and quality and must be kept in good working order.

*There is still a wide difference of opinion as to the advisability of laying the asphalt surface directly against the rail, many engineers preferring to set one or more courses of paving brick, or stone paving blocks between the rail and the edge of the asphalt. The writer's experience is to the effect that, if the work is properly done, the first-named form of construction is preferable. If the asphalt be laid against a rail so cold that the asphalt material in contact with or near the rail

ROCK ASPHALT PAVEMENT.

58. Rock asphalt paving surface shall be laid upon a concrete foundation prepared as specified in Articles 23, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34 and 35.

Material.

59. The material for a rock asphalt paving surface shall be a natural bituminous limestone or sandstone, or a mixture of two or more such materials. Rock asphalt shall be fine grained, of uniform texture and hardness, with the bitumen evenly distributed throughout the mass. It may contain not less than six and one-half ($6\frac{1}{2}$) nor more than twelve (12) per cent. by weight of bitumen, but the mixture laid upon the street shall not contain less than nine (9) nor more than ten (10) per cent. of bitumen not volatile at three hundred (300) degrees F., and, when necessary, richer or leaner rock asphalts must be combined to secure this result. As delivered, it shall be free from earth, rubbish and all extraneous matter. It shall be subject to such examinations and tests as the Engineer may deem necessary to determine its character and quality. Rock asphalts other than the standard products of the mines known as Val de Travers, Seyssel, Vorwohle, Limmer and Ragusa will not be accepted without the special permission of the Engineer, after full investigation, and pavements laid from such material shall be subject to the conditions of Section 43, and such other conditions and restrictions as he may prescribe.

Preparation.

60. The natural rock shall be broken and pulverized so that all will pass through a sieve having meshes or openings not larger than one-tenth (1-10) of an inch in their longest side or diameter. If the admixture of two or more varieties be necessary to secure the proper percentage and consistency of bitumen, the admixture will be made after pulverization and before heating, and in definite ratios by weight. The powder shall be heated in suitable apparatus to a temperature not exceeding two hundred and fifty (250) degrees F., care being taken that no part of it shall be burned, and it shall be conveyed to the street while hot.

is chilled before it can be compressed, the work will necessarily be unsatisfactory. As to durability, wheels following the line of the rail or of the paving blocks will sooner or later form a rut in the asphalt which will require repair;—and there is not much difference in the results. The attempts to prevent the formation of ruts by setting blocks alternately as headers and stretchers is not always successful, even when the work is well done, and the difficulty of properly compressing the tongues of asphalt between the headers is so great that it is usually not well done. The asphalt settles under travel or is gouged out, leaving a streak of rough pavement, and the difficulty and cost of repairs is considerably increased. When paving blocks or bricks are used, they should be firmly and carefully set in the concrete foundation. Probably the most satisfactory construction of this kind consists of two or three lines of the best paving brick set with their length parallel to the rail. It is somewhat easier to get at and repair rail joints with this construction.

Placing on the Street.

61. The mixture thus prepared shall be brought to the street in suitable wagons or carts, and when applied to the foundation its temperature shall not be below two hundred (200) degrees F. It shall be spread upon the street foundation in a uniform layer of such depth that after being fully compressed, it shall have a thickness of.....inches. The material shall then be thoroughly compressed by tamping, smoothing or rolling. The whole operation must be completed before the material has cooled to a temperature at which it ceases to be plastic. The completed surface of the pavement shall be sound and smooth and shall truly conform to the designed grade and contour of the street surface, and the completed surface shall comply with the template tests named in Section 55. Travel upon the street shall not be permitted until the asphalt surface becomes cold and hard.

Street Railroad Tracks.

62. Where railroad tracks exist in the street to be paved, the work along them shall be done in the same manner as prescribed for asphalt pavement, Section 56.

BLOCK ASPHALT PAVEMENT.

Sub-Grade and Foundation.

63. The sub-grade for asphalt block pavement shall be prepared in accordance with Section 23.

The foundation shall be of....., constructed as specified in Sections.....*

The upper surface of the foundation shall be at such grade as will bring the upper surface of the blocks, when laid, truly to the pavement datum.

Asphalt Blocks.

64. Asphalt blocks shall not be less than four (4) nor more than six (6) inches wide, ten (10) to twelve (12) inches long, andinches in depth.† Blocks for the same street must be of the same width and depth throughout, and no blocks varying more than three-sixteenths (3-16) inch from the standard dimensions will be accepted. Blocks that are chipped, cracked, or are otherwise imperfect shall be rejected.

Material and Composition.

65. Asphalt paving blocks will be composed of crushed trap rock, or equally hard and durable rock, pulverized stone, and asphaltic cement.

The crushed rock shall be of such sizes that all will pass a screen having meshes one-third (1-3) inch square, at least forty (40) per cent. shall be held on the number 20 sieve, and at least ten (10) per cent. shall pass the number 100 sieve. It must be free from dirt and other extraneous substances.

The pulverized stone shall comply with Section 47, and the asphaltum and asphaltic cement shall comply with Sections 41, 42, 43, 44, 45, 46, 47 and 49.

Making the Blocks.

66. The crushed rock, pulverized stone and asphaltic cement shall be heated and thoroughly mixed in suitable proportions, but the bitumen shall not fall below six and one-half ($6\frac{1}{2}$) nor exceed eight (8) per cent. of the whole. The quantity of pulverized stone shall not be less than ten (10) per cent. and may be increased to compensate for the absence of inorganic matter other than bitumen in the asphalt used. The asphaltic cement must not be heated to a temperature that will injure it.

*The practice of laying asphalt block pavement upon crushed stone, or a sand foundation, on streets carrying a considerable travel, is inadvisable. See foot-note, page 15.

†It is a common practice in a number of cities where blocks 4x6x12 inches are used, to lay them on their sides, making the depth dimension four inches. This is all right for private driveways and for streets of light travel; but for streets having considerable or heavy travel such blocks should always be set on edge, making the depth of the pavement six inches.

The hot mixture will be compressed in molds, under a pressure not less than four thousand (4000) pounds per square inch.* The completed blocks shall have a specific gravity of not less than two and one-half (2.5). When broken, the exposed surface shall appear compact and uniform in composition, without voids or spongy portions. When subjected to 1800 revolutions in the standard rattler for testing brick (Section 85), at a temperature of seventy (70) degrees F., the blocks shall not lose more than twelve (12) per cent. of their weight.

Laying the Blocks.

67. The foundation shall be first cleaned of dirt, rubbish or loose material.

When the blocks are four (4) inches or less in depth, they shall be set upon a bed of mortar made and applied to the foundation in the following manner:

The mortar shall be composed of Portland cement and sand, complying with the requirements of Sections 26 and 27 (a slow setting cement being preferred), in the ratio of one (1) part cement to four (4) parts of sand, thoroughly mixed with sufficient water to make a rather soft mortar. This mortar shall be spread over the foundation, which shall be previously wetted, in a layer approximately one-half ($\frac{1}{2}$) inch thick and its top graded by the use of templates to a surface at such depth below, and truly parallel to the pavement datum, that when the blocks are firmly set in it and rammed their tops will be in the true grade and contour of the pavement. The mortar shall be made and spread only as required in the progress of block laying, and any mortar that has begun to set before the blocks are in place and rammed, shall be removed and fresh mortar substituted. The blocks shall be set upon this mortar bed with their longest dimension across the street, in continuous courses which shall be straight and at right angles to the axis of the street. The block layers must stand upon the blocks already laid and not upon the mortar. The blocks and the courses of blocks shall be set as closely together as practicable. Blocks in adjoining courses must break joint not less than four inches. Whole blocks only will be used, except as fillers at the ends of the courses or in fitting the pavement around manholes or other structures, and where thus used the broken ends of the blocks must be dressed to make close joints. Unless otherwise permitted, each course must be laid continuously across the street without interruption in time. As each course is completed the end joints shall be forced close together by the use of wedges, levers or mauls. Upon the completion of every third course, the courses shall be forced together by placing a timber scantling against the face of the last course and striking it with a sledge or maul. When the blocks are thus laid, and before

*The pressure commonly specified is 5000 lbs. per square inch, but recent investigations make it doubtful if that pressure is ever attained, or is, indeed, practicable with any presses so far constructed.

the mortar under them begins to set, they shall be well rammed to a solid bearing in the mortar with a wooden street rammer weighing not less than thirty (30) pounds, a two-inch plank ten (10) inches wide and three (3) feet long being interposed between the block and the rammer and moved about so that the whole surface shall be covered and rammed. When the ramming is completed, the top of the blocks must conform so closely to the pavement datum that when a template or straight edge is placed upon the pavement, its surface shall nowhere depart from the true surface more than three-sixteenths (3-16) inch. Blocks, or portions of the pavement found too high or too low, must be taken up and reset in fresh mortar to the true grade. When thus completed to the satisfaction of the Engineer, a layer of one-half ($\frac{1}{2}$) inch of fine dry sand shall be placed over the surface and swept about with brooms until all joints are completely filled. The remaining sand shall be removed from the pavement at such time as the Engineer may direct.

When the depth of the blocks exceeds four (4) inches, they may be set upon a cushion-course of sand, as prescribed for brick pavement, Section 88, the joints to be filled with sand, as specified above in this Section.

Railroad Tracks.

68. Where railroad tracks exist on the street to be paved, the construction shall be the same as prescribed for granite block pavement, Section 80.

69. The street shall not be opened to travel until the mortar under the blocks shall have become fully set, and in no case under five days after the blocks are laid.

GRANITE BLOCK PAVEMENT.

70. Granite block pavement shall be laid upon a foundation of hydraulic cement concrete.*

Sub-Grade and Foundation.

71. The sub-grade shall be prepared as specified in Section 23. The foundation shall be constructed in accordance with the requirements of Sections 25, 26, 27, 28, 29, 30, 31, 32, 33, 34 and 35.

Granite Blocks.

72. The blocks shall be made from sound, durable granite, of uniform texture, composition and hardness throughout. No outcrop, deteriorated, soft, brittle, or seamy stone shall be used. If the blocks are obtained from different quarries, or from different parts of the same quarry where the quality or appearance of the rock differs, the product of each must be kept separate and laid together on the street.†

The blocks shall be not less than eight (8) nor more than thirteen (13) inches long, not less than three and one-half ($3\frac{1}{2}$) nor more than four and one-half ($4\frac{1}{2}$) inches wide, and not less than six and one-half ($6\frac{1}{2}$) nor more than seven (7) inches deep. They shall be well-shaped, rectangular, with full edges and corners. Their tops shall not depart more than one-half ($\frac{1}{2}$) inch from a true plane, and their sides shall be dressed so that joints between the courses will not be more than three-quarter ($\frac{3}{4}$) inch wide, and their ends so that end joints shall not be more than one-half ($\frac{1}{2}$) inch wide.‡ The size of the blocks may be varied where necessary to fit the pavement against or around bridge stones or other street structures.

Preparation of Foundation.

73. The foundation shall be cleaned of all dirt and rubbish. There shall then be spread evenly over it a layer of clean, coarse sand to a depth of one and one-half ($1\frac{1}{2}$) inches.

*Granite block pavement is, as a rule, used upon, and appropriate for streets of the heaviest class of travel, and should, therefore, be provided with the best and strongest foundation. It is nearly always poor economy to lay granite blocks upon a broken stone, gravel, or sand foundation.

†Like other stones, granite from various localities differs widely in strength, hardness and brittleness. Great hardness, accompanied with comparative brittleness, is not desirable in granite for paving blocks. Such material usually polishes by travel and becomes quite slippery, and it is likely to become "turtle-backed," that is, the corners are likely to be chipped off or worn off, making the pavement very rough and uneven.

‡As a rule, the closer the joints are made, the less likely are the paving blocks to become "turtle-backed," and the more likely is the pavement to wear down evenly, thus preserving an even and comparatively smooth surface.

Setting the Blocks.

74. The blocks shall be set in this bed of sand perpendicular to the street surface, with their length at right angles to the street, in courses extending entirely across the street, and at right angles to its axis, except at street intersections where the courses shall be set at such angle with the street as the Engineer may direct. Only stones of the same width shall be set in the same course. The stones in each course, and in adjoining courses, shall be set firmly against each other. The blocks shall be set in the sand bed in such a manner that their tops shall be even with each other and to such an elevation that after the pavement is rammed, as hereinafter directed, its general surface shall conform closely to the grade and contour designed for the pavement. Stones in adjoining courses shall break joint not less than three (3) inches.

Ramming.

75. After the blocks are set they shall be thoroughly rammed to give them a firm bearing in the sand and to bring their tops to the prescribed pavement datum. The rammers used shall have wooden faces, or, if rammers with iron faces are used, a two-inch plank, one foot wide and three feet long, shall be interposed between the blocks and the rammers. The rammers shall weigh not less than thirty (30) pounds. Blocks or sections of blocks whose tops under the ramming remain above or sink below the pavement datum shall be taken up and reset so that after the ramming is completed their tops shall coincide with the pavement datum.

Filling the Joints.*

76. After the ramming specified in Sect. 75 shall have been completed, the joints between the paving blocks shall be filled in the following manner:

All the joints for a distance of three feet out from the curb-stones, and three contiguous joints continuous across the street, with the included end joints, at intervals of about fifty (50) feet in the length of the street, shall be filled with gravel and bituminous paving cement. The gravel used shall be of such size that all will pass through a screen having five-eighths ($\frac{5}{8}$) inch meshes, and all will be held on a screen having one-fourth ($\frac{1}{4}$) inch meshes. When used, the gravel must be free from refuse and street dirt. The bituminous paving cement shall be composed of straight-run coal tar pitch of the hardness commonly known as number six, to

*It has been the almost universal custom, in this country at least, to fill the joints in granite paving with gravel and bituminous pitch. But the reasons that have led engineers to prefer grout filling for brick pavements apply with equal force to granite pavement. It makes a stronger and harder filling than the gravel and bituminous cement, and gives a better support to the edges of the paving blocks, thus tending to prevent chipping and "turtle-backing" in the pavement. It is also a materially cheaper filling than the gravel and bituminous cement. But to provide for the expansion and contraction of the pavement by changes of temperature, it is desirable that a strip in the gutters, and an occasional strip across the whole street, shall be filled with the more yielding material.

which has been added and thoroughly mixed, while both are in a melted condition, twenty per cent. (20%) by weight of refined Trinidad asphalt, or other asphalt, equal for the purpose, and twenty per cent. (20%) by weight of Portland cement. These ingredients must be thoroughly mixed, and kept agitated until used.*

The joints will first be filled with the gravel, perfectly dry, and heated so that when put in the joints it will be at a temperature of about three hundred (300) degrees F. The paving cement, heated to a temperature of about two hundred and fifty (250) degrees F., shall be at once, while the gravel is still hot, poured from a spouted vessel into the joints until the interstices of the gravel are entirely filled to the surface of the pavement, repouring being resorted to to accomplish this result.

All the joints in the pavement other than those named above shall then be completely filled with Portland cement grout, as follows:

The grout shall be composed of equal parts by volume of sand (Sect. 27) and Portland cement (Sect. 26), a quick-setting cement being preferred. The sand and cement shall be first thoroughly mixed dry and then enough water added to make a grout of such consistency that it will flow like thick cream, and the mixing continued until a homogeneous mass is produced and until the grout is applied to the pavement. The grout shall be prepared in water-tight boxes of a convenient size. Before applying the grout the pavement shall be thoroughly dampened by sprinkling. The grout shall be removed from the mixing box and spread over the pavement with scoop shovels, in two courses, the first being sufficient to about half fill the joints, and the second, which shall be applied before the first has begun to set, shall be sufficient to entirely fill the remaining space in the joints. As rapidly as the grout is applied it shall be swept about with brooms until it all enters the joints.

Order of Work.

77. The sand bed shall not be put in place more than fifty (50) feet ahead of the block setters. The ramming and filling of the joints shall follow closely the block setting, but no ramming shall be done within less than six (6) feet of the face of the block setting; and the final joint filling shall be kept completed to within twenty-five (25) feet of the ramming; but all the work rammed during any day shall have the joint filling completed before the cessation of work on that day. The street shall not be opened to travel until the grout has thoroughly set.

*The object of adding asphalt and Portland cement is to make the cement stronger and less susceptible to changes of temperature. Pure coal-tar pitch is very brittle at low temperatures, and is liable to flow from the crown of the street to the gutters in hot summer weather. A cement made as here specified is not only much stronger and less brittle in cold weather, but requires a materially higher temperature to cause it to flow than does pure pitch.

Fitting Paving Around Other Structures.

79. The size of blocks and the width of courses shall, as the block laying approaches bridge stones, curbs and other structures, or in making closures with other sections of pavement, be so selected and adjusted that joints not over three-quarters ($\frac{3}{4}$) inch in width shall result, without breaking blocks or splitting courses.

Street Railroad Tracks.

80. Where railroad tracks exist in the street the paving blocks shall be laid against the rail in the following manner:

The sub-grade and the pavement foundation shall extend under the rails uninterrupted except by the ties or other structures connected with the railroad track. For a distance of fourteen (14) inches, on each side of the rail, measuring from the center thereof, there shall be spread on the pavement foundation a layer of mortar not less than one and one-half ($1\frac{1}{2}$) inches thick, composed of one (1) part of cement and three (3) parts sand, complying with the requirements of Sections 26 and 27. Upon this layer of mortar shall be set, against the rail, and on each side of it, selected paving blocks, securely bedded in the mortar before it shall have begun to set.* Alternate blocks shall be long and short so as to break joint with the blocks of the adjoining pavement. Selected blocks with well dressed top surfaces shall be used and their tops shall be set as nearly as practicable at the level of the top of the rail, but not so high that the car wheels will ride upon them. In setting the blocks they shall be firmly bedded into the mortar by the use of paving hammers, but they shall not be thereafter rammed. As the blocks are set, any space between the paving blocks and the web of the rail shall be filled with mortar of the quality described above. The placing of these blocks shall not precede by more than ten (10) feet the block laying on the street. Care must be taken not to disturb the bedding of these blocks in the laying of the adjoining pavement, or otherwise. The joints shall be filled in the same manner as prescribed for the other portions of the pavement.

The construction along slot-rails shall be the same as described above, except that blocks of special size or shape may be required, as the Engineer may direct.

Bridge Stone Crossings.

81. Where directed by the Engineer, the old bridge stone, shall be redressed and relaid, as hereinafter specified for new bridge stone, and shall be moved from the point where taken up to the point where they are to be relaid, by the Contractor at his expense.

New bridge stone shall be of the same quality of granite as the paving blocks and free from imperfections. They shall not be less

*As the wheels of vehicles frequently follow along the lines of the rails, thus concentrating their effect on a narrow strip near the rails, and as the continuous joint against the rail makes the pavement weaker there, the mortar bed, and the greater care in setting the blocks along and near the rail are advisable.

than three and one-half ($3\frac{1}{2}$) nor more than six (6) feet long, eighteen (18) inches wide and of a uniform thickness not less than six (6) nor more than eight (8) inches, but these dimensions may be varied by the Engineer where necessary to fit the stone into special locations.

Their top shall be well dressed to a true plane surface not varying in evenness more than one-quarter ($\frac{1}{4}$) inch. The sides shall be dressed perpendicular to the face so as to joint closely against the paving blocks, and the ends shall be so dressed and to such a bevel that when set in the curved surface of the street, the joint between adjoining stones shall not be wider than one-quarter ($\frac{1}{4}$) inch from top to bottom.

Bridge stones shall be set in advance of the block laying, over the street foundation, in a bed of sand or gravel in which they shall be firmly bedded. Their upper surface shall conform truly to the pavement datum. They shall be set accurately to the lines given by the Engineer. Where the crosswalk requires more than one course of bridge stone, the courses shall be laid parallel to, and at such distance from each other as the Engineer may direct, and the space between courses shall be filled with paving blocks laid as specified in Sections 74, 75, 76 and 77.

BRICK PAVEMENT.*

Sub-Grade.

82. The sub-grade for brick pavement shall be prepared in accordance with Sect. 23 and shall be finished to a surface..... inches below and parallel to the pavement datum.

Foundation.

83. The foundation for brick pavement shall be of.....
.....† prepared in accordance with Sections.....
Its thickness shall be.....inches and its upper surface shall, when completed, be parallel to and at a depth below the pavement datum equal to the depth of the brick plus one and one-fourth ($1\frac{1}{4}$) inches. The surface of the foundation shall not vary more than one-half ($\frac{1}{2}$) inch above or below that depth.

Paving Brick.

84. The linear dimensions of paving brick may vary between the following limits: In length, from eight and one-half ($8\frac{1}{2}$) to nine and one-half ($9\frac{1}{2}$) inches; in width, from two and one-fourth ($2\frac{1}{4}$) to three and one-half ($3\frac{1}{2}$) inches; in depth, from four (4) to four and one-eighth ($4\frac{1}{8}$) inches; but the length shall not be less than three (3) nor more than three and three-fourths ($3\frac{3}{4}$) times the width. The corners shall all be rounded off to a radius of not less than one-eighth ($\frac{1}{8}$) nor more than three-sixteenths ($3\text{-}16$) inch. The brick for any one contract shall be all of the same kind and of the same standard size, and the individual bricks shall not vary in length more than three-sixteenths ($3\text{-}16$) inch, nor in width more than one-eighth ($\frac{1}{8}$) inch from the size adopted as standard.

The brick must be specially manufactured for paving purposes. They may be made from shale or from suitable clay. In either case the material must be thoroughly pulverized, mixed and tempered, and must be free from lime nodules or other substances that may disintegrate the brick when immersed in water. The brick shall be molded in efficient brick machines and repressed to a truly rectangular form, free from cracks, flaws and injurious laminations. After being properly dried the brick shall be properly and uniformly burned in down-draft kilns. Shale brick shall be burned to the

*The specifications here given for brick pavement follow closely the lines which experience has dictated, and conform closely to those recommended by the National Brick Manufacturers' Association.

†Here again a good concrete foundation is recommended, as being in the end the most satisfactory and economical. See foot-note, page 15.

point of incipient fusion or vitrification. After the burning is completed the brick shall be allowed to cool with sufficient slowness to insure thorough annealing.

The completed brick shall be free from flaws, cracks, ragged corners, and from such distortion or warping as will interfere with their utility or good appearance in the pavement. Paving brick shall not be salt-glazed.

85. The brick shall be subjected to the following tests to determine their quality:

When broken by the blows of a hammer the brick shall be strong and tough. The broken surface shall show a homogeneous composition throughout the broken section, free from flaws, injurious laminations, nodules and voids, and shall appear to be uniformly burned from surface to center.

When subjected to the standard "Rattler" test, in accordance with the rules adopted by the National Brick Manufacturers' Association, the average loss in weight shall not exceed eighteen (18) per cent., and the loss in weight of any individual brick in the test shall not be more than twenty-five (25) per cent. greater than the average loss of the whole charge.

When subjected to the absorption test, in accordance with the rules adopted by the National Brick Manufacturers' Association, shale bricks shall not absorb more than two (2) per cent. nor less than one-half ($\frac{1}{2}$) of one per cent. of their weight of water,* and clay bricks shall not absorb more than six (6) per cent. of their weight of water; the absorption of any individual brick shall not be more than fifty (50) per cent. greater than the mean absorption of the whole lot tested. Brick that do not successfully pass all these tests will not be accepted.

Samples.

86. Where samples of paving brick have been required and submitted by successful bidders, and tested as described above, it will be assumed that these samples fairly represent the quality of the brick to be subsequently supplied for the work, and brick that do not come up to the standard thus established will not be accepted.

Delivering Brick on Street.

87. Unless the sidewalks are too narrow to permit of it, the brick shall all be delivered upon the street before the foundation is constructed, and neatly piled upon the outer edge of the sidewalks, occasional openings being left in the piles for the accommodation of foot passengers. One-half the brick required shall be thus delivered and piled upon each sidewalk. In delivering the bricks from these piles to the bricklayers, they must be carried on pallets, or

*Absorption of less than one-half of one per cent, usually indicates that a shale brick has been over-burned, resulting in increased brittleness.

other suitable devices must be used; they must not be dumped from wheelbarrows upon the freshly-laid brick pavement.

If for any reason the bricks are not delivered before the foundation is laid, or if the sidewalks are too narrow to permit of the brick being stored upon them, they may be delivered over the foundation, but not until the concrete has set so hard that it will not be injured by transportation over it.

Sand Cushion.

88. Directly before the brick are laid into the pavement there shall be spread over the foundation a layer of sand one and one-half ($1\frac{1}{2}$) inches in depth. The sand shall be free from vegetable or other refuse matter, and shall not contain more than five (5) per cent. of clay and loam. Pebbles and fragments of stone exceeding one-half inch in diameter must be screened out. When spread on the street the sand shall be sufficiently dry to permit of proper gaging by templates, as hereinafter described. The sand shall be spread and correctly gaged to the proper thickness and surface by the use of templates formed to the true designed cross-sectional contour of the pavement. If the width of the street between curbs does not exceed twenty-five (25) feet, the template shall be made in one length sufficient to cover the full width of the street, and its ends shall be so constructed and fitted with iron rollers, that it will rest upon and roll along the top of the curb at each end; if the width of the street between curbs be not more than fifty (50) feet the template shall be of sufficient length to reach from the curb to the middle of the street, and constructed to move on rollers on top of the curb at one end and upon a plank six (6) inches wide and one and one-half ($1\frac{1}{2}$) inches thick laid upon the foundation along the center line of the pavement. The template shall be worked forwards and backwards along the line of the street until the surface of the sand conforms exactly to the designed contour of the pavement, at a depth below the pavement datum equal to the depth of the paving brick minus one-fourth ($\frac{1}{4}$) inch. When completed the surface of the sand cushion shall be smooth and unbroken, and care must be taken not to disturb it before the bricks are set upon it.

Setting the Brick.

89. Several courses of brick, aggregating a strip having a width of not less than twelve (12) inches nor more than fifteen (15) inches on each side of the street, beginning against the curb, shall be first laid, the brick being set with their long dimension parallel to the curb.* The pavement intervening between these gutter courses will then be set in courses at right angles to the axis of the street, except in street intersections, where the courses shall make an angle of forty-five (45) degrees with the axis of the street. The brick shall be set upon edge on the sand cushion with their

*The object of this is to make a gutter offering less obstruction to the flow of water.

faces parallel to the pavement datum, in straight courses, continuous across the street, the long dimension of the brick being parallel to the courses; they shall be set as closely together as possible, so that the joints both between the courses and between individual bricks shall not exceed one-eighth ($\frac{1}{8}$) inch. Broken bricks and bats shall not be used except as closures at the ends of the course and in fitting the pavement around manholes, etc., and nothing smaller than half-bricks shall be used in either case, and the broken ends must be shaped to make reasonably close joints.

Inspection.

90. After the bricks are laid the pavement will be inspected by the Engineer, or his agent. He may require that the surface shall be previously wetted by sprinklers, or by a sprinkling nozzle, in order to detect soft or porous bricks.* Defective bricks indicated by him shall be removed and replaced by acceptable brick.

Rolling and Ramming.

91. The surface of the pavement shall then be rolled and rammed in the following manner:

The roller used shall be of the asphalt roller style, driven by steam and weighing not less than three and one-half ($3\frac{1}{2}$) nor more than five (5) tons. The rolling shall begin as near the curb as practicable, the roller being operated slowly, parallel to the axis of the street, and working outwardly until the center of the street is reached, when the roller will proceed to the opposite side of the street and the operation proceed as before. After this longitudinal rolling is completed the pavement will be continuously rolled a second time, the roller operating back and forth at an angle of forty-five degrees to the axis of the street, and a third time, the roller operating at right angles to the course of the second rolling. After the rolling is thus completed the brick in the gutters not reached by the roller shall be rammed with a street rammer weighing not less than fifty (50) pounds, a plank not less than six (6) feet long, ten (10) to twelve (12) inches wide and two (2) inches thick being interposed between the pavement and the rammer and moved about so that the whole surface of the gutter shall be thoroughly and equally rammed and its surface brought to an even junction with the rolled portion of the work.

When the rolling and ramming is thus completed the surface of the pavement shall conform so truly to the designed pavement datum that it will nowhere depart more than three-sixteenths ($\frac{3}{16}$) inch from properly-formed templates and straight-edges applied to its surface.

Filling the Joints.

92. Directly after the completion of the rolling and ramming, the joints between the bricks shall be filled as follows:

*This is the simplest and most effective way to detect soft and underburned brick.

The joints in the longitudinal gutter courses, and the joints between six contiguous courses running across the street, from gutter to gutter, in each length of fifty (50) feet of the pavement, shall be filled with bituminous cement composed of coal-tar pitch, commercially known as Number Six, to which has been added fifteen (15) per cent. of refined Trinidad asphalt and twenty (20) per cent. of hydraulic cement, all by weight.* In preparing this bituminous cement, the pitch shall first be melted and the asphalt, also melted, added and thoroughly incorporated by agitation. The hydraulic cement shall then be added and the whole agitated until a complete and uniform mixture results. The bituminous cement thus prepared shall be, while sufficiently hot and liquid to flow freely, poured from a spouted vessel into the joints until they appear to be nearly or quite full. After allowing time for the filling to subside, the joints will be gone over a second time and completely filled, care being taken to confine the cement to the joints and not to deposit it on the surface of the pavement.

All the remaining joints in the pavement shall be filled with Portland cement grout, as follows:

The grout will be composed of equal parts by volume of sand (Sect. 27) and Portland cement (Sect. 26), a quick-setting cement being preferred. The sand and cement shall be first thoroughly mixed dry and then enough water added to make a grout of such consistency that it will flow like thick cream, and the mixing continued until a homogeneous mass is produced and until the grout is applied to the pavement. The grout shall be prepared in water-tight boxes of a convenient size. Before applying the grout the pavement shall be thoroughly dampened by sprinkling. The grout shall be removed from the mixing box and spread over the pavement with scoop shovels, in two courses, the first being sufficient to about half fill the joints, and the second, which shall be applied before the first has begun to set, shall be sufficient to entirely fill the remaining space in the joints. As rapidly as the grout is applied it shall be swept about with brooms until it all enters the joints.†

93. Travel must be excluded from the pavement until the grout has set firmly; in no case less than five days.

*See foot-note, page 40.

†The bituminous-cement joints are principally for the purpose of providing for the expansion of the pavement in very hot weather.

Experience seems to have proved that cement grout is, everything considered, the best and cheapest filling for the joints in brick pavement. If the filling is properly done, the edges of the brick are supported and the corners do not chip off. With the expansion joints provided at intervals by the bituminous-filled joints, the curbs will not be forced out of line, nor will the pavement be raised from its sand bed by expansion, causing the rumbling sound sometimes noticed.

WOOD-BLOCK PAVEMENT.

Sub-Grade.

94. The sub-grade for wood-block pavement shall be prepared as specified in Section 23, and shall be finished to a surfaceinches below the pavement datum.

Foundation.

95. The foundation for wood-block pavement shall be Portland cement concrete.....inches thick, prepared as specified in Sections 25, 26, 27, 28, 29, 30, 31, 32, 33, 34 and 35. The upper surface of the concrete foundation, when completed, shall be at a distance below the pavement datum equal to the depth of the blocks to be laid, plus one-half ($\frac{1}{2}$) inch, and must not vary more than one-fourth ($\frac{1}{4}$) inch above or below that depth.

MATERIALS.

Wood-Blocks.

96. The wood-blocks shall be of Southern long-leaved Yellow Pine, Loblolly Pine of slow growth, White Oak, Chestnut or Red Oak, White Elm, Red Gum, or other species of wood, which, in the opinion of the Engineer, are equally as strong and durable as those named, and of a texture permitting satisfactory preservative treatment, as hereinafter specified; but all the blocks for any one contract shall be of the same species of wood.* Only wood from live, sound trees shall be used. The lumber from which the blocks are cut shall be properly manufactured, free from bark, and with full square corners. It shall be free from decay, dotiness, brashness, shakes, large season cracks, loose or unsound knots over three-fourths ($\frac{3}{4}$) inch in diameter, and all other imperfections which may, in the opinion of the Engineer, be detrimental. "Fat" pine containing so much resin that it will not take up the specified quantity of creosote oil in treatment may be rejected. Second-growth timber, and Southern pine showing, outside of a radius of three (3) inches from the heart, ten (10) or less annual growth rings to the inch, will not be accepted

*Since immunity from early natural decay is secured by preservative treatment, the important requisite for wood paving blocks is capacity to withstand the wear and tear of the travel on the street. We have no very satisfactory data as to the ability of the various species of wood to endure the somewhat peculiar and special duty to which paving blocks are subjected.

The test which seems to most nearly approach to what is wanted is that of crushing strength, when the force is applied to the end of the sample, parallel to its fibers; but this does not embrace the effect of impact to which paving blocks are subjected under street travel. Whether this may be considered a function of the end-crushing strength or

The paving blocks, cut from the lumber above specified, shall be well manufactured, truly rectangular and of uniform dimensions. Their depth, (parallel to the fiber) shall be.....inches,* their length shall be not less than seven (7) nor more than twelve (12) inches, and their width shall be not less than three (3) nor more than four (4) inches; but all the blocks for any one contract shall be of the same depth and width. Their depth and width shall not vary more than one-eighth ($\frac{1}{8}$) inch from the dimensions specified.

Creosote Oil.

97. The oil used for preservative treatment, commercially known as creosote oil, shall be Dead Oil of Coal Tar, without adulteration. Oil known to the trade as "Wood Creosote Oil" will not be accepted. The dead oil of coal tar shall not contain more than one and one-half ($1\frac{1}{2}$) per cent. of water, nor more than 5% of tarry matter. Its specific gravity, at 60 degrees F., shall not be below 1.02 nor above 1.07. Subjected to distillation no part

not is an open question, though there seems good reason to believe that it will prove to be so; and if so, there is no good reason why woods of substantially equal strength under the end-crushing test should not show about the same endurance under street travel, independent of the element of natural durability, which is practically eliminated by preservative treatment. The most complete set of tests of the endwise compression of different species of wood yet available to the engineer, is that made under the direction of the Division of Forestry, U. S. Dept. of Agriculture, the results of which were published in Circular Number 15, of that Division. The average strength, in a dry condition, under endwise compression, of the several woods enumerated as acceptable in these specifications, is given, as follows:

Southern Long-Leaved Yellow Pine.....	6900
Loblolly Pine	6500
White Oak.....	8500
Chestnut Oak.....	7200
Red Oak.....	7200
White Elm	6500
Red Gum	7100

Other species of the oak family, as Overcup Oak, Burr Oak, Post Oak, Spanish Oak and Water Oak, all show a resistance to end crushing of over 7000 pounds per square inch. In the absence of even presumptive reasons to the contrary, and in the absence of actual experience, it is reasonable to conclude that all these woods can be safely used, after proper preservative treatment, for street paving purposes. The Red Gum (Liquidambar Styraciflua), more commonly known in the middle Mississippi valley as Sweet Gum, seems to possess qualities that make it peculiarly suitable for street paving blocks, and its comparative cheapness, compared with Yellow Pine and the oaks, is a strong recommendation.

There seems to be no good reason why Long-Leaved Yellow Pine should alone be specified as acceptable, as it has been in most cases heretofore, particularly as the lumber now marketed under that name almost always contains a large percentage of short-leaved or bastard pine, a distinctly inferior wood.

*The question of the most economical depth for wood paving blocks is as yet unsettled. In New York City, blocks 3 1-2 inches in depth are adopted as the standard and are being used on streets of the heaviest travel, the practice of Berlin, Paris and other foreign cities being thus followed. The arguments in favor of these short blocks are lower first cost, and that, with much deeper blocks, the usual uneven wear of a wood pavement will make it so rough as to require removal before the blocks are worn down so as to be split up and dislodged from their places. While reliable data on these points are wanting, it seems to the writer very unwise to use such short blocks on streets of heavy travel, and he would recommend that the minimum length for use on such streets be 4 1-2 inches, and he would prefer 5 inches.

On streets of light travel a length of 3 1-2 inches should be satisfactory.

of it shall be volatile at a temperature of 300 degrees F., and it shall not lose by evaporation more than 20% in weight when maintained at a temperature of 400 degrees F. for four (4) hours. With increased temperature it shall yield not less than 45% nor more than 55% of naphthaline. The residue, after exposure in a shallow dish to a temperature of 650 degrees F. for three (3) hours, shall not exceed 10% of the original weight. The oil, freed from water, shall be wholly soluble in carbon disulphide.

Preservative Treatment.

98. The paving blocks shall, after they are cut to the proper dimensions, be subjected to preservative treatment, as follows:

The blocks, thrown loosely into an open-work iron receptacle, or truck, shall be placed in an iron or steel vessel or cylinder, and subjected to heat, gradually rising to a temperature not below 255 degrees F., nor above 265 degrees F., and this temperature shall be maintained for a period of four hours. The temperature shall then be allowed to decline to about 240 degrees F. The air shall then be exhausted from the cylinder until a vacuum of not less than twenty-four (24) inches is produced, and the creosote oil specified in Article 97, at a temperature of about 200 degrees F., shall be admitted to the cylinder, the vacuum being maintained during the admission of the oil. When the blocks are all well submerged in the oil the vacuum shall be discontinued, and hydraulic pressure of not less than one hundred (100) pounds per square inch shall be gradually applied, and continued for not less than two (2) hours, or until every part of each block shall be permeated with the oil, all the blocks being kept submerged in the oil until the completion of the process.

The quantity of creosote oil in the blocks, after treatment, shall be at least ten (10) pounds per cubic foot of wood.* The remaining oil shall then be withdrawn and the blocks removed from the cylinder.

In the preliminary heating of the blocks, either dry heat produced by steam coils in the cylinder may be employed, or steam at a pressure of thirty (30) pounds per square inch may be admitted directly into the cylinder and that pressure maintained for a period of four (4) hours. In either case the extracted sap and condensed fluids must be kept drained from the cylinder.

*The only office of the preservative treatment is to prevent, or at least to retard, natural decay, since it is well understood that none of the common preservative processes adds anything to the strength and wearing qualities of the wood. It follows that the thoroughness of the treatment should be inversely as the time the pavement is expected to last. For streets of light travel, where the pavement would not wear out short of twelve or fifteen years, the treatment should be very thorough, and 15 to 20 pounds of oil per cubic foot should be injected, dependent upon the capacity of the wood to absorb the oil; on the contrary, where the travel is so heavy that the pavement cannot be expected to endure for more than five to seven years, the preservative treatment is not so important, and the injection of eight or ten pounds of oil per cubic foot would usually be ample.

Special Processes.

99. Special preservative processes involving the use of resin, pitch or other substances admixed with creosote oil, may be used, provided that the treated wood shall contain not less than ten (10) pounds of creosote oil per cubic foot of wood, and provided further that the substances thus mixed with the creosote oil shall not, in the judgment of the Engineer, be in themselves deleterious, and shall not in any way neutralize the value and preservative properties of creosote oil. The Engineer may require such evidence and make such tests at the expense of the Contractor as will satisfy him upon these points.*

Laying the Wood-Blocks.

100. Upon the concrete foundation shall be spread a layer of mortar made of one (1) part of Portland cement, and three (3) parts of sand, complying with Sects. 26 and 27, with sufficient water to make a moderately stiff paste.† The mortar shall be thoroughly mixed, and shall be spread in place on the foundation immediately in advance of the block laying, to such a thickness that when the blocks are set and properly bedded in the mortar their tops shall conform accurately to the designed grade and contour of the street. The concrete foundation shall be cleaned and swept to remove all extraneous matter and shall then be thoroughly dampened, immediately in advance of placing the mortar bed. The mortar bed shall be "struck" by templates to a surface truly parallel to the pavement datum.

Upon this mortar bed the blocks shall be carefully set on end, or with their fiber vertical, in straight, parallel courses, either perpendicular to the axis of the street, or at such angle thereto as the Engineer may direct. The blocks shall be set as closely

*The writer has little confidence in the beneficial effect of adding resin, coal tar, or other substances to the dead oil, and would require that a sufficient quantity of the oil should be injected to itself preserve the wood. It is true that pine woods when completely saturated with resin (as they are often found in nature) are almost completely preserved from decay, but when the wood is imperfectly saturated, the resin seems to have but little effect, and it is very difficult, if not impossible, to produce complete saturation by artificial processes. The claim that the use of the resin prevents moisture from entering the wood, might, if true, make its use important. The claim is undoubtedly true of freshly treated whole blocks, since the surface is coated and sealed against water. But the resin does not penetrate or saturate the pores of the wood to much depth, and when the blocks become slightly worn and their fibers "broomed," they absorb water almost as freely as plain creosoted wood. The sealing effect is, therefore, but temporary and of little value.

†It is a common practice of contractors in some cities, in the laying of both wood block and asphalt block pavement, where a mortar bed is called for, to substitute a bed of mixed sand and cement, dampened only to such a degree as will make the mass pulverulent like damp sand, the claim being made that ordinary mortar cannot be spread and gaged properly. This claim is unfounded. The objection to the practice is that the dampened mixture does not contain sufficient water to cause the cement to set, and with the practically water-tight paving surface, does not receive, even in rainy weather, the necessary amount of water. If the weather be dry, the small quantity of moisture in the mixture quickly evaporates, leaving the so-called mortar bed not much better than a layer of sand alone. The writer has found such alleged mortar soft and unset two weeks after the pavement had been completed. If real mortar is not to be used, a layer of sand might almost as well be substituted at first.

together as practicable. After the blocks are thus set in place, they shall be rammed with a street rammer weighing not less than thirty (30) pounds, a plank ten (10) inches wide, two (2) inches thick and not more than six (6) feet long, laid flat on the pavement, being interposed between the rammer and the blocks and moved about until the blocks are rammed to a firm seat in the mortar bed and their tops brought truly to the designed pavement datum. The ramming shall be completed before the mortar bed has begun to set, but no ramming shall approach nearer than three (3) feet to the edge of the block setting, except where the block setting may be interrupted, as at the end of a day's work, when all the blocks then set shall be rammed. Mortar that may have begun to set before the blocks are in place and rammed shall be discarded and replaced with fresh mortar. The top surface of the pavement, when laid, shall conform truly to the grade and contour of the street. Correctly-formed templates twelve (12) feet long, placed on the pavement, shall show at no place a departure of more than three-sixteenths (3-16) inch from the true pavement datum.

101. After the block setting is completed, perfectly dry fine sand shall be spread over the pavement surface and swept about until every joint into which the sand will penetrate shall be completely filled. The remaining sand shall be left upon the pavement for such time as the Engineer may direct, when it shall be removed by the Contractor.*

Chamfered Blocks.

102. Where wood-block pavement is laid on streets or parts of streets having a gradient of more than 3%, the blocks shall not be less than four (4) inches long, and the upper side-corners of the blocks shall be chamfered to a depth of three-eighths ($\frac{3}{8}$) inch, the chamfered surface to make an angle of 40 degrees with the vertical sides of the blocks; or such other construction shall be used as will, in the opinion of the Engineer, provide an equally good foot-hold for horses.

Expansion Joints.

103. Before the blocks are set there shall be placed along and against each curb a board having a width two (2) inches greater than the depth of the blocks, three-fourths ($\frac{3}{4}$) inch thick at its top edge and one-half ($\frac{1}{2}$) inch thick at its bottom edge. The paving blocks at the beginning and end of each course shall be set against this board. After the ramming of the blocks has been completed, these boards shall be carefully withdrawn and the space between the curbs and the paving blocks shall be completely filled with the bituminous paving cement described in Section 76.

104. The street shall not be opened to travel until such time as the mortar under the blocks shall have become well set, nor until the Engineer shall so direct.

*In a number of cities the specifications require the joints in wood-block pavement to be filled with Portland cement grout. If the blocks are set as closely together as they should be, the joints will be so narrow

GENERAL, RELATING TO ALL PAVEMENTS.

Connection With Existing Pavements or Streets.

105. Wherever a new pavement joins or abuts against an existing pavement of a different kind, or an unpaved street, either at the end of the new pavement or at cross or intersecting streets, a line of stone headers shall be provided and set. The stone shall be of sound, hard limestone, sandstone, granite or bluestone, free from injurious imperfections. The separate stones shall be not less than three (3) feet long, not less than four and one-half ($4\frac{1}{2}$) inches wide at the top, nor less than three (3) inches wide at the bottom. The top shall be of uniform width for each line of headers, and shall be dressed square and even. The ends shall be dressed to secure a joint not wider than one-half ($\frac{1}{2}$) inch for a depth of six inches from the top, and the sides dressed so as to secure good contact and close jointing with the pavement. The stones shall be set with their tops at the pavement datum, on a bed of concrete nine (9) inches wide and six (6) inches deep, and after being set the trench shall be filled and rammed full of gravel or crushed stone.

All existing pavements adjoining or abutting against the new pavement, with their crosswalks, curbs and gutters, shall be adjusted, or taken up and relaid, to conform to and connect with the pavement datum, to such an extent as the Engineer may direct.

Where the new and adjoining pavement are of the same kind, and headers are not used, the new and the old pavement must be properly joined and connected, as the Engineer may direct.

106. Stone headers will be paid for by the linear foot at the contract price for that item, and the other work embraced in this section will be paid for at the contract prices for the several items, where such contract prices are provided; otherwise the work shall be considered as incidental work and shall be done at the expense of the Contractor.

Measurement and Estimates.

107. Pavements will be paid for by the square yard of actual surface completed and accepted, deducting all sewer, manhole or other openings in it of two (2) square feet or more in area. Openings under two (2) square feet in area will be measured and estimated as a part of the pavement surface.

The price paid per square yard for pavement shall cover and include the supplying of all the materials required and all the labor necessary to fully complete the work, except such materials and

that no grout, thick enough in consistency to be of value, will enter them, except for a short distance down from the top, the remaining depth of the joints remaining unfilled.

An examination of any well-laid wood-block pavement soon after it has been attempted to fill the joints with grout will verify this statement. Furthermore, the oil which exudes from the blocks, acting on the thin films of grout, seems to deteriorate the mortar and to render it practically inert. On the contrary, fine dry sand will readily run into and completely fill the joints, and under travel the joints will soon become impervious to water. The sand filling is therefore regarded as better, and it costs less than the grout filling.

labor for which unit or lump sum prices are provided and named in the contract. In the case of asphalt pavement the price for the pavement shall cover both the base and the surface courses.

Guaranty.*

108. The Contractor shall guarantee that all the materials used and all the work done under this contract shall fully comply with the requirements of these specifications, the plans hereinbefore referred to and the instructions of the Engineer. Any defects in the completed work, or any part of it, or any failure of the work to fully perform or endure the service for which it was intended, which, in the opinion of the Engineer, are attributable to the use of materials, skill, or workmanship not in compliance with the said specifications, plans and instructions, that may appear in the work, or any part of it, within a period of.....years after the date of the certificate of completion and acceptance, shall be regarded as prima facie and conclusive evidence that the Contractor has failed to comply with the said specifications, plans and instructions. And the Contractor shall, at his own expense, at such time and in such manner as the Engineer may direct, repair or take up and reconstruct any such defective work, in full compliance with the original specifications, plans and instructions. And as surety for the performance of this guaranty the Contractor's bond, required by the contract, shall remain in full force until the expiration of the period of.....years above stipulated in this section.

Terms of Payment.

109. Upon the last day of each full calendar month in which the work shall have been in progress, the Engineer will estimate approximately the quantities of material delivered and of work done, preceding that date, and determine the percentage which the value of the materials delivered and the work thus done is of the estimated value of the whole work, at the contract prices, when completed. Eighty per cent. of the value so determined, less any previous payments made, will be paid to the Contractor on or before the fifteenth day of the succeeding month. But such partial payments shall not be construed as an acceptance by the city of any materials furnished or work done.

Within thirty days after the final completion of the work, and its acceptance by the Engineer, as evidenced by his final estimate and certificate of completion and acceptance, any balance remaining due to the Contractor will be paid to him, provided that such certificate of acceptance and final payment shall in no way invalidate or release the Contractor from the provisions of Section 108.

*As outlined in the introduction, these specifications are designed to secure the construction of the pavement in a proper manner, the city assuming responsibility for the character and utility of the work. The guarantee here proposed is therefore intended to cover only a proper compliance with the specifications, for which the contractor may properly be held responsible, and not the sufficiency or utility of the work, if constructed according to the specifications. The period of guaranty should therefore be short, not exceeding two years.

GENERAL SPECIFICATIONS FOR EXPERIMENTAL OR UNTRIED PAVEMENTS.*

110. Contractors or promoters submitting proposals for the construction of new, experimental, or special street pavements, the merits of which have not been established by experience in the city of....., must submit with their proposal a full and complete set of specifications for the construction of the pavement. If contract shall be awarded under said proposal, said specifications will be made a part of the contract entered into. The Engineer will enforce compliance with these specifications, as the construction work proceeds, without assuming or incurring any responsibility for the character, quality, serviceability or durability of the resulting pavement. But the Contractor shall be subject to and shall comply with the requirements and stipulations of Sects. 1 to 22, inclusive, and of Sects. 105, 106 and 107, of these specifications.

Special Guaranty.

111. Inasmuch as the pavement to be constructed under the special specifications submitted by the Contractor is more or less of an experimental character, having not been heretofore used in the city of.....to an extent sufficient to establish its value, the Contractor shall be held wholly responsible for the utility, serviceability and durability of the pavement so constructed; and he shall enter into a guaranty to the effect as follows:

That the pavement will fulfill all the usual and legitimate requirements of a satisfactory roadway pavement upon the street upon which it is to be laid.

That the pavement will successfully serve and endure the travel to which the street may be subjected for a period ofyears next following the date of the certificate of its completion and acceptance, and shall be in good condition at the end of that period, ordinary and reasonable wear and tear, and accidental or other injuries not due to defects in the pavement itself, excepted.

That the Contractor will, at his own cost, keep the said pavement in satisfactory repair during said period of..... years, and will leave it in a condition of satisfactory repair at the end of that period.

Upon the general subject of time guarantees of municipal work, see Chapter XI, "Municipal Public Works," by the writer.

*In this class of pavements the contractor or promoter may properly be required to assume responsibility for the character and utility of the work produced, and the municipal authorities should assume no part of such responsibility.

That the Engineer, or his successor or successors in office, shall be the sole and final judge as to whether the conditions of this guaranty shall be, or shall have been complied with.

That in case the pavement shall not, in the judgment of the Engineer, fulfill the terms and conditions of this guaranty at any time during said period of.....years, or upon its expiration, or in case the Contractor shall fail to make all or any of the repairs that may in the judgment of the Engineer be or become necessary during said period of.....years, within a reasonable period to be determined by the Engineer, but not to be less than twenty (20) days after notice to make such repairs has been given him by the Engineer, he (the Engineer) may proceed to make or to have made such repairs, or to repave the street, in any manner that he may deem necessary or advisable, and to charge the cost of such repairs or repavement to the Contractor, provided, that the sum or sums so charged against the Contractor shall not, in the aggregate, be more than the amount paid to the Contractor for the construction of the pavement.

Bond.

112. The Contractor shall give bond with sureties satisfactory to the Engineer in a sum not less than the estimated cost of the pavement at the contract prices, the term of the bond to extend over the entire period of.....years, for which the pavement is guaranteed.

113. During the said period of.....years the Contractor shall, upon being notified by the Engineer so to do, make any repairs to the pavement that may become necessary by reason of cutting into it for the purpose of constructing or repairing pipes, conduits or other underground structures, or street railroad tracks, or by reason of accidental or unusual causes, or of any causes other than those due, in the opinion of the Engineer, to the failure of the pavement to meet and fulfill the terms of the guaranty stipulated in Section 111.

And for making such repairs the Contractor shall be paid the price of..... per square yard of the repairs actually so made. Repairs so made shall be subject to the terms of the guaranty, stipulated in Section 111, until the expiration of the said term of.....years after the date of the original certificate of completion and acceptance. In case the Contractor shall neglect or fail to make such repairs within a period of twenty (20) days after he shall have received notice to do so, the Engineer may proceed to make or to have made such repairs, and he shall charge to and collect from the Contractor the cost of the repairs so made.



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